Climatic Factors and Its Effect on Chili Production: One Step Forward Combating Climate Change

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Abstract. The impacts of climate change are increasingly visible from time to time, where it's also arisen in the agricultural sector, including chili cultivation. In order to solve this problem, we need to know how climate factors actually impacts chili production. This study aimed to find out which and how climate factors impacted chili production, also the optimum point of each factor in regard of its impact on chili production. In this study, we used secondary data from the Food and Agriculture Organization (FAO) and the Climate Change Knowledge Portal (World Bank) with data ranging from 1961 to 2021 (61 years). Regression analysis using a quadratic model is used to determine the impact of climatic factors on chili production. The analysis shows that the mean and minimum temperatures, followed by rainfall have a significant impact on chili production with an optimum point of 25.20°C; 20.95°C; and 2,751.54 mm respectively.
Keywords : Climate Change, Chili Production, Regression Analysis, Climatic Factors, Optimum Conditions

1 Introduction

Chili is one of the strategic commodities in Indonesia, according to [1], the cumulative consumption of chili in Indonesia is 490.83 thousand tons in 2021 as it is also the highest consumption in the last 5 years. It also indicates that the demand for this commodity is high. Therefore, stability in chili production needs to be achieved to be able to meet market demand. East Java is the largest chili producing province with a cumulative contribution of 36.17% of Indonesia's total chili production. Followed by Central Java and West Java with respective contributions of 14.54% and 13.73% [2].

Chili production is influenced by many factors, both factors that can and cannot be managed by farmers. Some factors that can be managed by farmers include land area, seeds, manure, pesticides and labor. These factors have an influence on chili production [3]. On the other hand, factors that contain risks and uncertainties that cannot be controlled such as

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weather and climate also affect chili farming. According to the reports from [4], the global average temperature in 2022 was 1.02 to 1.28 °C above the 1850-1900 average, of which 2015-2022 was the eighth warmest year documented with 2022 being the 5th or 6th warmest year.

Climate change has an impact on many aspects of life, including chili farming activities. According to [3] weather and climate factors can reduce production efficiency and chili farming income in Garut Regency. Additionally, expected climate changes will likely cause higher temperatures, heavy rainfall, and drought that have adverse effects on the vegetative and generative development of chili peppers [5]. In accordance with the 13th goal in the SDGs, namely taking urgent actions combating climate change and its impacts. Before fighting climate change, it is necessary to know how the direct impact of climate change is on chili production so that demand for this commodity can still be achieved. On the other hand, by knowing the effect, we can find ways to minimize the impact of climate change on chili production. Climate change in this case is seen through changes in maximum temperature, minimum temperature, mean temperature and rainfall.

2 Methods

This research was conducted using secondary data, namely chili production and climatic factors consisting of maximum temperature, minimum temperature, mean temperature and rainfall for 61 years with a range from 1961-2021. Chili production data was obtained from FAOSTAT, while data on climate factors was obtained from the Climate Knowledge Portal, World Bank. Time series data with a long-time span were chosen to be able to see the effects of climate change over a long period of time, based on the definition of the World Meteorological Organization [6], normal climate standards refer to data for the last 30 years.

In conducting analysis using time series data, the stationarity test is one of the things that must be done. The stationarity of time series data has a great influence, where the inability to render time series data into the correct stationarity form will produce spurious results [7]. Therefore, before carrying out the regression analysis, the Augmented Dickey Fuller stationarity test is carried out to prevent the emergence of these problems. The results of the stationarity test can be seen in table 1 where all variables are stationary at the 1st difference.

Table 1. Augmented Dickey-Fuller Test Results

Variable	Stage	ADF Statistic	Prob.	Information
Production	1st difference	-7.820085	0.000	Stationary
Max Temp	1st difference	-7.576772	0.000	Stationary
Min Temp	1st difference	-8.623053	0.000	Stationary
Mean Temp	1st difference	-7.621957	0.000	Stationary
Precipitation	1st difference	-6.998396	0.000	Stationary

Source: Secondary Data Analysis (2023)

After all data is stationary, quadratic regression is performed to determine climatic factors that affect chili production. The advantage of this analysis is that we can also find out the optimum point of each climate variable. The general equation used in this regression is as follows:

$$Y = \beta_0 + \beta_1 X_i + \beta_2 X_i^2 + u_i \tag{1}$$

Where Y is the dependent variable, X is the independent variable, while β_0 indicates a constant value and β_1-β_2 are variable coefficients while u_i describes the error term. It was also explained that there was only one independent variable in this model. but these variables can appear in several kinds of exponents, so this model is included in multiple linear regression. This model can be analysed using the usual OLS method and does not violate the assumption of collinearity [8]. The equation model used in this study is as follows:

$$Y_t = \alpha_0 + \alpha_1 max_t + \alpha_2 maxsq_t + \varepsilon \quad (2)$$

$$Y_t = \alpha_0 + \alpha_1 min_t + \alpha_2 minsq_t + \varepsilon \quad (3)$$

$$Y_t = \alpha_0 + \alpha_1 mean_t + \alpha_2 meansq_t + \varepsilon \quad (4)$$

$$Y_t = \alpha_0 + \alpha_1 rain_t + \alpha_2 rainsq_t + \varepsilon \quad (5)$$

Where Yt describes the chili production in year t, α_0 is the constant, $\alpha_1 - \alpha_2$ represents the variable coefficient, max_t, min_t, $mean_t$, and $rain_t$ are maximum temperature, minimum temperature, mean temperature, and rainfall in year t respectively. Meanwhile $maxsq_t$, $minsq_t$, $meansq_t$, and $rainsq_t$ are the squared value. Based on the results of this regression analysis, the optimum point value will be obtained which indicates a change in the direction of the chili production rate in Indonesia. There are 4 possibilities in carrying out a quadratic regression analysis:

1. Increases at an increasing rate, when 1st order derivative > 0 and 2nd order derivative > 0;
2. Increases at a decreasing rate, when 1st order derivative > 0 and 2nd order derivative < 0;
3. Decreases at an increasing rate, when 1st order derivative < 0 and 2nd order derivative < 0;
4. Decreases at a decreasing rate, when 1st order derivative < 0 and 2nd order derivative > 0.

3 Result and discussion

3.1 Effect of mean, minimum, and maximum temperature on chili production

Temperature is an important factor for chili growth in addition to nutrition, light and other factors. According to Lu et. al [9], yield deviations are more susceptible to temperature changes than sunlight and rainfall. The impact of temperature changes can also result in an increase in pest attacks and a decrease in yield quality. This study analyses the effect of mean temperature, minimum temperature, and maximum temperature on chili production in Indonesia. Quadratic regression results for the mean temperature variable can be seen in table 2.

The results of the analysis show that the average temperature affects chili production in Indonesia. Based on the F test, the average temperature and average temperature squared together affect chili production. Partially, the average temperature and the mean squared temperature significantly influence the 10% alpha. The average temperature coefficient is 21,589,234, which means that every 1°C increase in average temperature will increase chili production in Indonesia by 21,589,234 kilograms per hectare with an optimum average temperature of 25.56°C. When the average temperature has reached the optimum temperature, it will decrease the rate of increase in chili production. The optimum temperature for the growth of chili plants is 24°C-30°C [10].

Table 2. Quadratic regression results of mean temperature

Variable	Coefficient	Std. Error	t-Statistic	Prob
Inflection Point	25.556			
C	45414.51**	17201.01	2.640223	0.0107
D(MEANT)	21589234*	11799074	1.830503	0.0724
D(MEANTSQ)	-422563.7*	229390.4	-1.842116	0.0707

Source: Primary Data Analysis (2023)

* = significant at 10% alpha; ** = significant at 5% alpha

Based on FAO data (2023) Indonesia's average temperature for the last 61 years (1961-2021) is 25.75°C with an increasing trend. In 1985, Indonesia's average temperature was 25.56°C which is the same as the optimum point, in that year there was an increase in production of 0.2%. But after that year, Indonesia's average temperature exceeded the optimum point. Even so, the trend of Indonesian chili production tends to increase and the average temperature is still within the temperature range where chili can grow.

The effect of minimum temperature on chili production also shows a significant effect (table 3). An increase of 1°C minimum temperature and minimum temperature squared will increase chili production in Indonesia by 13,786,168 tons per hectare until it reaches an optimum temperature of 20.946°C, after exceeding this value, it will reduce the rate of increase in chili production. The development of the minimum temperature in Indonesia is also the same as the development of the average temperature which has an increasing trend. Starting from 1986-2021 the minimum temperature in Indonesia exceeded 21°C (average minimum temperature 21.39°C) which indicated an increase in the minimum temperature compared to previous years (1961-1985) with an average minimum temperature of 20.84°C. If only based on the influence of minimum temperature data, chili production continued to increase from 1961 to 1985, but after 1985 the rate of increase in chili production would decrease because it had passed the optimum point. Moekasan et al. [11] stated that good air temperature for the growth of chili plants is 25-27°C during the day and 18-20°C at night. Night temperatures below 16°C and daytime temperatures above 32°C can thwart fertilization.

Table 3. Quadratic Regression Results of Mean Temperature

Variable	Coefficient	Std, Error	t-Statistic	Prob
Inflection Point	20.946			
C	45390.19*	17084.80	2.6568	0.0102
D(MINT)	13786168*	6497568.0	2.1217	0.0382
D(MINTSQ)	-329090.0*	153870.2	2.1388	0.0368

Source: Primary Data Analysis (2023)
* = significant at 10% alpha

In addition to the average temperature and minimum temperature, high temperature is also one of the main factors that can affect chili production. High temperatures can limit the growth and development of several crops grown in Asia, including rice, wheat, potatoes, tomatoes and chilies [12]. The effect of global warming with projected temperature increases of 1°C to 3°C in the 21st century can affect crop yields due to long-term temperature increases and will affect the survival rate and production of cultivated plants[13].

Table 4. Quadratic Regression Results of Maximum Temperature

Variable	Coefficient	Std. Error	t-Statistic	Prob
Inflection Point	30.209			
C	45305.61*	17311.71	2.617050	0.0113
D(MAXT)	29032056^{ns}	17637795	1.646014	0.1053
D(MAXTSQ)	-480505.8^{ns}	290676.7	-1.653059	0.1038

Source: Primary Data Analysis (2023)
* = significant at 10% alpha; ns = non-significant

The results showed that the optimum temperature for chili cultivation was 30.209°C. Based on the F test, the maximum temperature and the squared value simultaneously affect chili production. However, partially both variables have no effect on chili production. Meanwhile, the effect on this model is an increasing at decreasing rate, where the maximum temperature increase will increase chili production, but after passing the optimum point, the rate of increase in production will decrease. The growth temperature of chili during the vegetative phase ranges from 21°C -27°C, while for the generative phase it ranges from 16°C -23°C [14]. If the temperature is too low or too high it will damage the quality of the fruit produced. The effect of temperature and humidity in accordance with chili plants is a temperature of 27°C which produces higher plant height, stem diameter, and number of leaves compared to other temperatures.

3.2 Effect of rainfall on chili production

Current weather and climate conditions are constantly changing, affecting rainfall patterns. Changing rainfall patterns certainly have an influence on activities in the agricultural sector, such as changes in the growing season which results in a decrease in crop yields. Planting seasons that are not in accordance with rainfall conditions can have an impact on crop failure or decreased production, this discrepancy results in opportunities for pests and diseases in chili plants.

Table 5 describes the results of quadratic regression which shows the effect of rainfall on chili production. Based on the F test, rainfall and quadratic rainfall together affect chili production in Indonesia. Partially, rainfall and quadratic rainfall have a significant effect on alpha 10%. The rainfall coefficient is 2290.650, which means that an increase in rainfall by 1 mm will increase chili production by 2290.650 kilograms per hectare with an optimum rainfall point of 2751.544 mm. When rainfall has reached optimum, the increase in the amount of rainfall will reduce the rate of increase in chili production. Rainfall in 2005 was very close to the optimum point, namely 2743.29 mm, but in that year chili production decreased. This was due to a decrease in land area of 7352 ha, based on FAO data (2023).

Table 5. Quadratic Regression Results of Rainfall

Variable	Coefficient	Std, Error	t-Statistic	Prob
Inflection Point	2751.544			
C	44580.76**	17161.09	2.597782	0.0119
D(PRE)	2290.650*	1046.879	2.188076	0.0328
D(PRESQ)	-0.416248*	0.193023	-2.156473	0.0353

Source: Primary Data Analysis (2023)
* = significant at 10% alpha; ** = significant at 5% alpha

The existence of climate change has the potential to reduce crop yields which causes farmers to adapt to climate change. Studies conducted by Hidayati & Suryanto [15] shows that farmers who experience decreased yields, and farmers who are in dry areas will make decisions to change cropping patterns and shift planting times as a form of adaptation to climate change. It is important for farmers to have knowledge of seasons and their behavior as well as knowledge of biological resources in order to be able to choose commodities, cropping patterns and planting times [16]. Other technical efforts can be made by using superior seeds, adjusting the use of fertilizers, for example in the rainy season farmers choose fertilizers that do not contain much N (Nitrogen) elements and during the dry season use fertilizers with a higher N content [17]. During high rainfall, farmers can do pruning and make drainage channels [16]. The adaptations adopted by vegetable farmers are shifting planting seasons and changing cropping patterns. In addition, it can modify irrigation techniques, drainage, tillage, and pest control techniques. Other efforts that can be carried out include mapping climate-appropriate commodities, developing various types and varieties resistant to climate stress, applying climate information, developing soil and plant processing technology to increase plant adaptability, and developing farming protection systems from failures due to climate change [18].

4 Conclusions

Climatic factors that have a significant effect on chili production are average temperature, minimum temperature, and rainfall, while maximum temperature has no significant effect. All models tested have a quadratic shape with an optimum point of 25.556°C (mean temperature); 20.946°C (minimum temperature) and 2751.544 (rainfall). Even though climate factors have an effect on chili production, the effect is not too big because there are many other factors outside the model that also affect chili production. Nonetheless, climate factors still have a significant influence on chili production so that farmers as farming actors, the government as policy makers, and other related parties need to anticipate climate change by adapting to technology.

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