

Data Analytics on the Effect of Climate Change to the Production of Fruit Plants during 2014-2020 in Malang District

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ABSTRACT

Horticultural products are agricultural commodities that have strategic value not only for farmers, but also for market players and consumers in Indonesia. In 2019, the GRDP of horticultural products in East Java reached IDR31.13 trillion. Compared to other districts in East Java, Malang District is the most contributor to horticultural products in East Java. However, the development of horticultural agriculture recently embraces various problems and challenges, one of which is the climate change factor. Meanwhile, new knowledge about the peak harvest times for each year, new strategies regarding crop rehabilitation times, and others are still less explored. Based on these problems, this research presents data analytics on the effect of climate change to the productivity of fruit plants during 2014 to 2020 in Malang district using multiple linear regression and correlation analysis. In this study, we can conclude that the peak harvest time for fruit tends to occur in the October–December. In those months, the rainfall (225.78 mm per month) was classified as moderate, and the temperature level (25.24 °C) with humidity (78.87%) were classified as optimal. Meanwhile, the low harvest time occurs in other months with too high or too low level on those three parameters namely rainfall, temperature, and humidity.

Keywords: Horticulture, Harvest, Rainfall, Temperature, Humidity.

1. INTRODUCTION

Horticultural products are agricultural commodities that have strategic value for producers, market players, and consumers in Indonesia. Based on macroeconomic indicators, including gross domestic product (GDP), the number of households involved in farming, and the farmer exchange rate (NTP), horticultural products can provide a large enough contribution to state income. The GDP of horticultural products in 2019 reached IDR 238.8 trillion [1] with 10.1 million agricultural business households and the farmer exchange rate (NTP) reaching 102.25 in 2020 [2]. Meanwhile, the Gross Regional Domestic Product (GRDP) of horticultural products in East Java reached IDR31.13 trillion. Compared to other districts in East Java, Malang

District is the most contributor to horticultural products in East Java.

Public awareness of the importance of horticultural products is also increasing, not only as food but also providing benefits for health and environmental sustainability. The increasing demand for horticultural products also continues to go up in line with the population growth. Thus, to supply market demand, efforts should be made to increase the productivity of horticultural commodities sustainably. However, the development of horticultural agriculture is faced various problems and challenges, one of which is the climate change factor [3].

However, studies related to the impact of climate change on horticultural commodities are still rarely carried out. So far, studies related to the effect of climate change in Indonesia have focused more on

food crops, while horticultural commodities are still very limited. Therefore, studies related to the impacts of climate change (rainfall, temperature, and humidity) on the production of fruits commodities were carried out to obtain new knowledge about the peak harvest times for each year, new strategies regarding crop rehabilitation times, and other related strategies (with a case study in Malang district).

In studies related to the impact of climate change on fruit crop productivity, the role of data analytics becomes crucial. With data analytics, every decision-making process to increase fruit production will always be based on the results of previous data analysis. So, decision-making can be done quickly and be more focused. The expected contribution from the results of this study is a new insight. It can be used as a basis on the decision-making process to increase productivity and the sustainability of the horticultural crop production system optimally. In addition, it can be used to develop the right strategy in minimizing the impact of climate change which has caused losses and reduce agricultural yields.

2. METHODOLOGY

This study uses secondary data from Statistics Indonesia. The data are the production data of horticultural crops (fruits) and climate change parameter from Malang district during the period of 2014 to 2020. The commodities selected to represent horticultural crops (fruits) are avocado, apple, durian, orange, mango, papaya, banana, and salak. Climatic parameter data to determine climate change are rainfall, air temperature, and humidity from the climate observation stations AR Saleh airfields, Karangates, and Karangploso, Indonesia.

The stages in this research are as follows: (1) Collecting and analyzing climate parameter data (rainfall, air temperature, and humidity) to determine patterns of climate change during the period of 2014 to 2020; (2) Collecting and analyzing crop yield data to determine the yield patterns of fruit crops (avocado, apple, durian, orange, mango, papaya, banana, and salak) during the period of 2014 to 2020; (3) Applying multiple linear regression analysis to determine the effect of climate change (rainfall, air temperature, and humidity) on fruit yields. The analysis was done on each product (avocado, apple, durian, orange, mango, papaya, banana, and salak); (4) Applying multiple linear correlation analysis to determine the level of influence of climate change (rainfall, air temperature, and humidity) on fruit yields each

product (avocado, apple, durian, orange, mango, papaya, banana, and salak).

2.1. Climate

Climate is defined as an area's long-term weather patterns. The simplest way to describe climate is to look at average temperature and precipitation over time. Other useful elements for describing climate include the type and the timing of precipitation, amount of sunshine, average wind speeds and directions, number of days above freezing, weather extremes, and local geography [4]. The climate of any particular place is influenced by a host of interacting factors. These include latitude, elevation, nearby water, ocean currents, topography, vegetation, and prevailing winds [5].

Climate is a factor that can affect the growth process and crop yields, both in quality and quantity. These climatic elements include rainfall, air temperature, and humidity which affect the metabolic processes of plants. Rainfall can affect the availability of water for plants. Water is needed by plants as a chemical solvent in plants and controlling plant temperature. Meanwhile, air temperature can affect energy activation and enzyme inactivation in plants. And humidity can affect the transpiration of substances in plants [6].

2.2. Fruit Plants

Fruit plants are a type of horticultural plant other than vegetable plants, medicinal plants, and plantation plants, which in whole or part of the fruit can be consumed fresh or after processing. Several types of fruit are categorized as primary commodities because they have high economic value, have broad market opportunities, and have high production potential. Some of the major fruit crop commodities include avocado, apple, mango, durian, salak, orange, papaya, and banana.

Avocado plants can grow in the lowlands and highlands, ranging from 5–1500 meters above sea level. The minimum rainfall for growth is 750–2500 mm per year. In addition, the optimal temperature for avocado growth ranges from 12.8–28.3°C, and the required humidity is between 70–85% [7,8]. Apple plants can grow and bear fruit at an altitude of 700–1200 meters above sea level. Apple plants require ideal rainfall for growth between 1000–2600 mm per year. In addition, the optimal temperature for growing apples is between 16–27°C, and the required humidity is between 75–85% [8,9].

The mango plant is a lowland plant. This plant can thrive in areas with an altitude between 1–300

meters above sea level. Mango plants require ideal rainfall for growth between 750–2250 mm per year. In addition, the optimal temperature for mango growth is between 24–27°C, and the required humidity is between 70–85% [8,10]. Durian plants can thrive in areas with an altitude of 50–1200 meters above sea level. Durian plants require ideal rainfall for growth between 1500–3000 mm per year. In addition, the optimal temperature for durian growth is between 20–30°C, and the required humidity is between 70–85% [8,11].

Orange plants can thrive in areas with an altitude of 1–1200 meters above sea level. Orange plants require ideal rainfall for growth between 1000–3000 mm per year. In addition, the optimal temperature for orange plant growth is between 20–30°C, and the required humidity is between 70–80% [8,12]. Papaya plants can thrive in areas with an altitude of 700–1000 meters above sea level. Papaya plants require ideal rainfall for growth between 1000–2000 mm per year. In addition, the optimal temperature for papaya plant growth is between 22–26°C, and the required humidity is between 70–85% [8,13].

Banana plants can thrive in areas with an altitude of 1–2000 meters above sea level. Banana plants require ideal rainfall for growth between 1520–3800 mm per year. In addition, the optimal temperature for banana plant growth is between 22–32°C, and the required humidity is between 70–85% [8,14]. Salak plants can thrive in areas with an altitude of 100–1000 meters above sea level. Salak plants require ideal rainfall for growth between 1200–2500 mm per year. In addition, the optimal temperature for salak plant growth is between 20–27°C, and the required humidity is between 75–85 % [8,15].

2.3. Multiple Linear Regression Analysis

A multiple linear regression model is an equation that describes the relationship between two or more independent variables or predictors (x_1, x_2, \dots, x_n) and one dependent variable or response (y). The purpose of multiple linear regression analysis is to predict the value of the dependent variable or response (y) if the values of the independent variables or predictors (x_1, x_2, \dots, x_n) are known. The following is the formula for multiple linear regression equations [16]:

$$y = a + b_1x_1 + b_2x_2 + \dots + b_nx_n \quad (1)$$

where: y — dependent variable; a — constant; b_1, b_2, b_n — regression coefficient; x_1, x_2, x_n — independent variable.

2.4. Multiple Linear Correlation Analysis

Multiple linear correlation coefficient is used to determine the level of correlation between the variables of x_1, x_2, \dots, x_n simultaneously with the variable of y . The value of multiple linear correlation coefficient can be calculated by the formula [16]:

$$r = \sqrt{\frac{(b_1 \sum x_1 y) + (b_2 \sum x_2 y)}{\sum y^2}} \quad (2)$$

if the r -value approaches the value +1 or -1, then the correlation between x and y is higher. However, if the r -value nears the zero value, the correlation between x and y is lower. Positive sign (+) indicates a direct relationship, and negative sign (-) indicates a reversed relationship.

3. RESULTS AND DISCUSSION

3.1. The Climate of Malang District

Malang District is located at an altitude between 0–2000 meters above sea level at coordinates 112° 17' 10.9" to 112° 57' 0.0" East Longitude, and 7° 44' 55.11" to 8° 26' 35.45" South Latitude. Based on climate data during 2014 to 2020, rainfall in Malang district ranges from 1 to 374.89 mm per month with an average rainfall of 180.36 mm per month. Relatively high rainfall (more than 300 mm per month) occurs in December, January, February. Meanwhile, from June to October, the rainfall is relatively low (less than 100 mm per month). The increase and decrease in rainfall can be affected by the altitude of an area. The temperature in Malang District ranges from 22.99–25.68°C with an average air temperature of 24.51°C. Air temperature fluctuations can be affected by altitude and duration of sun exposure in an area. The humidity in Malang District ranges from 71.78–86.22% and average humidity to 79.81%. Air humidity is the amount of water vapor in the air. The fluctuations of air humidity can be affected by changes in air pressure.

3.2. The Productivity of Fruits in Malang District

Harvest on fruit plant is carried out every three months in a year. The first harvest was carried out in January to March (first quarter), the second harvest was in April to June (second quarter), the third harvest was in July to September (third quarter), and the fourth harvest was carried out in October to December (fourth quarter). Based on

data on fruit yields from 2014 to 2020, the production of several fruit commodities in Malang district has fluctuated every quarter. It is influenced by climatic changes such as rainfall, air temperature, and humidity that occur every quarter.

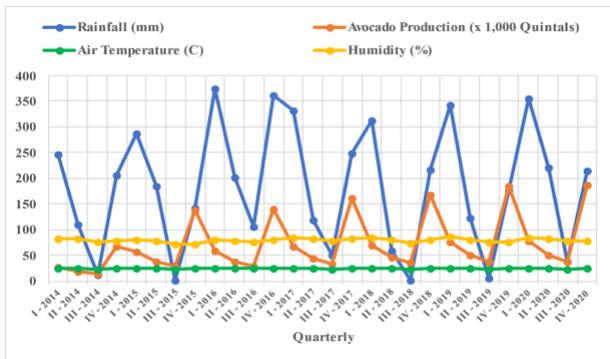


Figure 1. Graph of Climate and Avocado Production (2014 to 2020)

For avocado commodities, the highest yields often occur in the fourth quarter (18,441 tons in 2019 and 18,617 tons in 2020) with an average rainfall of 225.78 mm per month, an average air temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occurred in the third quarter (3,840 tons in 2019 and 3,877 tons in 2020) with an average rainfall of 30.91 mm per month, an average air temperature of 23.40 °C, and the average air humidity is 76.13%.

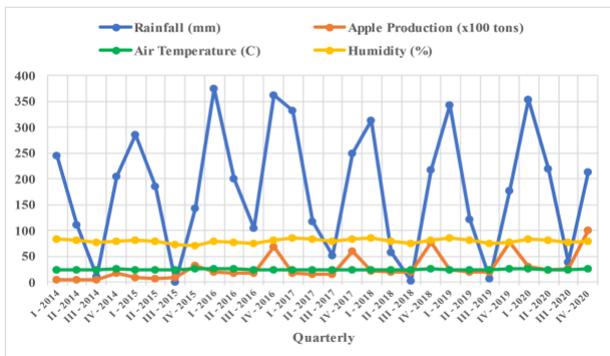


Figure 2. Graph of Climate and Apple Production (2014 to 2020)

For apple commodities, the highest yields often occur in the fourth quarter (7,800 tons in 2019 and 10,103 tons in 2020) with an average rainfall of 225.78 mm per month, an average temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the second quarter (1,900 tons in 2019 and 2,461 tons in 2020) with an average rainfall of 145.17 mm per month, an average air temperature of 24.63 °C, and the average air humidity is 80.62%.

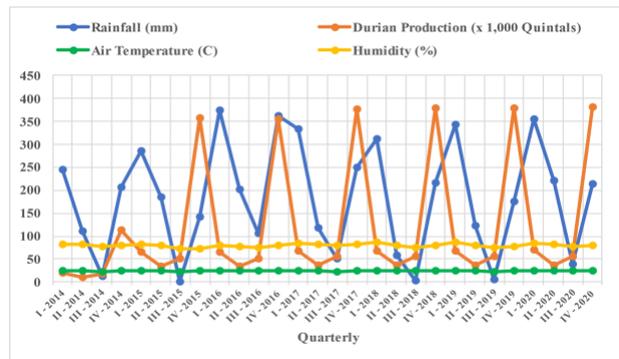


Figure 3. Graph of Climate and Durian Production (2014 to 2020)

For durian commodities, the highest yields often occur in the fourth quarter (38,043 tons in 2019 and 38,178 tons in 2020) with an average rainfall of 225.78 mm per month, average temperature of 25.24 °C, and the average humidity is 78.87%. Meanwhile, the lowest yields occur in the second quarter (3,748 tons in 2019 and 3,762 tons in 2020) with an average rainfall of 145.17 mm per month, average temperature of 24.63 °C, and the average humidity is 80.62%.

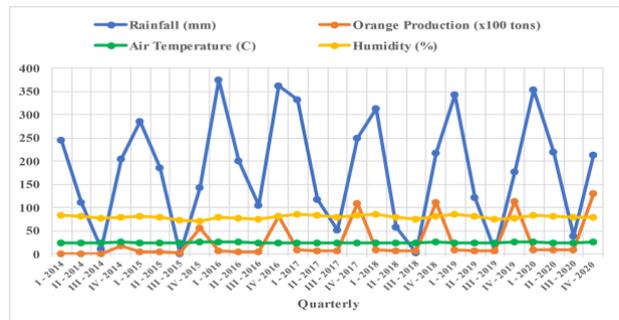


Figure 4. Graph of Climate and Orange Production (2014 to 2020)

For orange commodities, the highest yields often occur in the fourth quarter (11,240 tons in 2019 and 13,008 tons in 2020) with an average rainfall of 225.78 mm per month, an average temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the third quarter (704 tons in 2019 and 815 tons in 2020) with an average rainfall of 30.91 mm per month, an average air temperature of 23.40 °C, and the average air humidity is 76.13%.

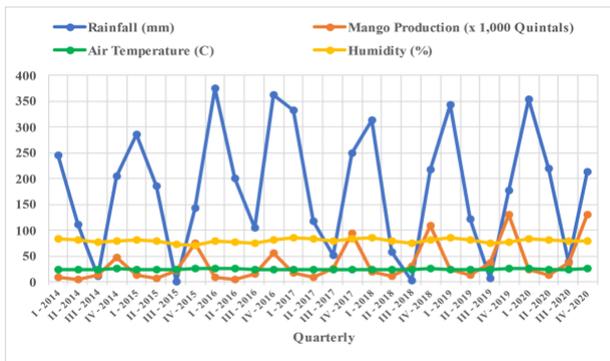


Figure 5. Graph of Climate and Mango Production (2014 to 2020)

For mango commodities, the highest yields often occur in the fourth quarter (12,985 tons in 2019 and 13,075 tons in 2020) with an average rainfall of 225.78 mm per month, an average air temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the second quarter (1,348 tons in 2019 and 1,357 tons in 2020) with an average rainfall of 145.17 mm per month, an average air temperature of 24.63 °C, and the average air humidity is 80.62%.

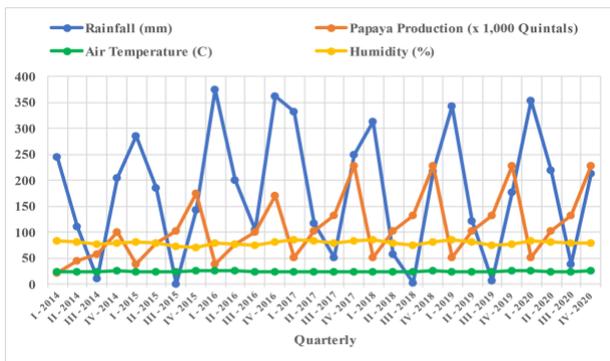


Figure 6. Graph of Climate and Papaya Production (2014 to 2020)

For papaya commodities, the highest yields often occur in the fourth quarter (22,889 tons in 2019 and 22,890 tons in 2020) with an average rainfall of 225.78 mm per month, an average air temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the first quarter (5,092 tons in 2019 and 5,094 tons in 2020) with an average rainfall of 319.59 mm per month, an average air temperature of 24.79 °C, and the average air humidity is 83.62%.

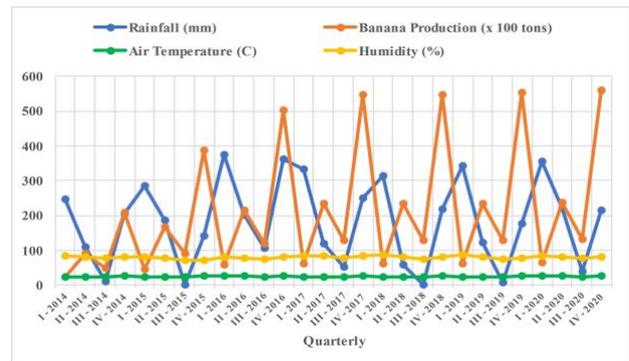


Figure 7. Graph of Climate and Banana Production (2014 to 2020)

For banana commodities, the highest yields often occur in the fourth quarter (55,233 tons in 2019 and 55,927 tons in 2020) with an average rainfall of 225.78 mm per month, an average air temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the first quarter (6,312 tons in 2019 and 6,391 tons in 2020) with an average rainfall of 319.59 mm per month, an average air temperature of 24.79 °C, and the average air humidity is 83.62%.

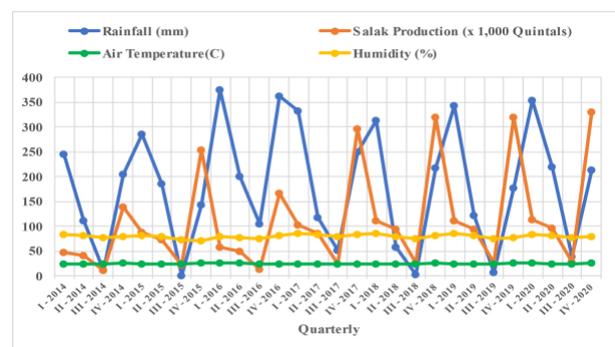


Figure 8. Graph of Climate and Salak Production (2014 to 2020)

For the salak commodities, the highest yields often occur in the fourth quarter (32,040 tons in 2019 and 33,007 tons in 2020) with an average rainfall of 225.78 mm per month, average air temperature of 25.24 °C, and the average air humidity is 78.87%. Meanwhile, the lowest yields often occur in the third quarter (2,667 tons in 2019 and 2,748 tons in 2020) with an average rainfall of 30.91 mm per month, an average air temperature of 23.40 °C, and the average air humidity is 76.13%.

3.3. Multiple Linear Regression and Correlation Analysis

This study analyzed the relationship between all independent variables (rainfall, air temperature, and humidity) simultaneously with the dependent variable (fruit yield). Thus, the F-test was used on multiple linear regression and correlation analysis. The F table value in this test is 2.99. Based on F-test results, there is a relationship between rainfall, temperature, humidity, and fruit yields (avocado, durian, banana, and salak). It is indicated by the significance value from fruit yields of avocado ($\alpha_1 = 0.007$), durian ($\alpha_1 = 0.015$), bananas ($\alpha_1 = 0.022$), and salak ($\alpha_1 = 0.004$) which are lower than $\alpha_0 = 0.05$. In addition, the F-count value from fruit yields of avocado (F-count = 5.168), durian (F-count = 4.286), bananas (F-count = 3.859), and salak (F-count = 5.923) were higher than F-table (2.99).

However, it is different for commodity apples, oranges, mangoes, and papayas. Based on F-test results, there is no relationship between rainfall, air temperature, humidity, and yields (apples, oranges, mangoes, and papayas). It is indicated by the significance value from fruit yields of apples ($\alpha_1 = 0.095$), oranges ($\alpha_1 = 0.055$), mangoes ($\alpha_1 = 0.087$), and papayas ($\alpha_1 = 0.103$) which are higher than $\alpha_0 = 0.05$. In addition, the F-count value from fruit yields of apples (F-count = 2.379), oranges (F-count = 2.916), mangoes (F-count = 2.465), and papayas (F-count = 2.299) were lower than F-table (2.99).

3.4. The Effect of Climate Change on Productivity of Fruits

There is a relationship between rainfall and yields of several fruit commodities (such as avocado, durian, banana, and salak). Changes in rainfall intensity can trigger pest and disease attacks on fruit

crops. When rainfall is high, disease attacks on plants will increase. However, when rainfall is low, pest attacks on plants will increase [17]. In fruit crops such as durian, salak, banana, and avocado, rainfall determines the production process. High rainfall during the flowering and fruiting phase can cause the loss of flowers and fruit seeds. In fruit ripening process, high rainfall also accelerates fruit rot, thus damaging the quality of the fruit [18,19,20].

In addition, rising air temperatures can affect the intensity of plant pest attacks. Rising air temperatures can affect the life cycle of pests, and high temperatures will speed up their life cycle [17]. Rising air temperatures can reduce fruit quality, such as damaged fruit pigments, decreased sugar levels in fruit, and decreased vitamin content in fruit. Harvest and post-harvest of fruits are also affected by temperature. Poor harvests and improper storage can destroy the nutritional content of the fruit and speed up the process of fruit rot [6].

Besides the influence of rainfall and air temperature, air humidity also affects the transpiration of substances in plants. The optimum humidity for plants is 70–90%. If agricultural land has low humidity, plants will need water to carry out the photosynthesis process. However, if the humidity is too high, fungi and bacteria will grow. Fungi and bacteria will cause damage to plants or fruit [18].

Based on the results, we found that fruit crops such as avocado, apple, mango, durian, salak, orange, papaya, and banana will produce high yields during moderate rainfall (100–300 mm per month). Moderate rainfall occurs in October to December. However, these fruit crops will produce low yields when rainfall is too high or too low. The lowest yields for avocados, oranges, bananas, and salak

Table 1. Multiple Linear Regression & Correlation Analysis

Dependent Variable	Independent Variable (Rainfall, Air Temperature, and Humidity)			
	α_1	F-Count	Coefficient Correlation	Correlation
Avocado	0.007	5.168	0.626	Strong
Apple	0.095	2.379	-	Uncorrelated
Durian	0.015	4.286	0.591	Moderate
Orange	0.055	2.916	-	Uncorrelated
Mango	0.087	2.465	-	Uncorrelated
Papaya	0.103	2.299	-	Uncorrelated
Banana	0.022	3.859	0.570	Moderate
Salak	0.004	5.923	0.652	Strong

occur at low rainfall (less than 100 mm per month). Low rainfall occurs in July to September. When rainfall is high (more than 300 mm per month), the yield of apple, mango, durian, and papaya crops will decrease compared to yields during moderate rainfall (October to December). However, the lowest yields of apples, mangoes, durians, and papayas will occur in April to June. It confirms that fruit crops such as avocado, apple, mango, durian, salak, orange, papaya, and banana will produce optimum harvests during moderate rainfall (100–300 mm per month).

In addition, we also found that the optimum temperature for the yield of fruit crops such as avocado, apple, mango, durian, salak, orange, papaya, and banana is around 25°C. The air temperatures below 25 °C will affect crop yields so that crop yields will decrease. Meanwhile, the optimum air humidity for crop yields is around 78–79%. The air humidity below 78% or above 79% will affect crop yields so that crop yields will decrease. It confirms that fruit crops such as avocado, apple, mango, durian, salak, orange, papaya, and banana will produce optimum harvests when the temperature is around 25 °C and the humidity is between 78–79%.

4. CONCLUSION

Based on the result of this study, it can be concluded that the rainfall during 2014 to 2020 in Malang district ranges from 1 to 374.89 mm per month with an average rainfall of 180.36 mm per month. Relatively high rainfall (more than 300 mm per month) occurs in December, January, February. Meanwhile, from June to October, the rainfall is relatively low (less than 100 mm per month). The air temperature in Malang District ranges from 22.99–25.68°C monthly, and the average air temperature of 24.51°C monthly. In addition, the humidity in Malang District ranges from 71.78–86.22% monthly, and the average humidity of 79.81% monthly. The production of several fruit commodities (avocado, apple, durian, orange, mango, papaya, banana, and salak) during 2014 to 2020 in the Malang district always fluctuates during the harvest period (quarter). However, the highest fruits production often occurs in October to December (fourth quarter) for all fruit commodities (avocado, apple, durian, orange, mango, papaya, banana, and salak). Meanwhile, the lowest production yield for each fruit commodity often occurs in a certain quarter. The lowest production of avocado, orange, and salak often occur in July to September (third quarter). The lowest production of

apples, durian, and mango often occurs in April to June (second quarter). Moreover, the lowest production of papaya and bananas often occur in January to March (first quarter). The regression results show that there is a relationship between rainfall, air temperature, humidity, and crop yields (avocado, durian, banana, and salak). However, for the commodity such as apples, oranges, mangoes, and papayas, the cases are different. Statistically, the regression results showed no relationship.

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