The Effect of Rainfall Anomalies on the Productivity of Clove Plants (*Syzygium aromaticum*) and Management Strategies in Southeast Sulawesi

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Abstract.
Climate change has caused rainfall anomalies that have an impact on decreasing the productivity of clove plants (Syzygium aromaticum). This study aims to analyze extreme rainfall anomalies in North Buton Regency and Kolaka Regency, assess its impact on the productivity of clove plants (Syzygium aromaticum), and formulate management strategies that can be applied to increase crop yields. The method used is a quantitative descriptive approach with linear regression analysis to determine the relationship between rainfall and clove productivity. The research population is clove farmers in North Buton Regency and Kolaka Regency, with a sample of three farmers in each village where the research is located. Rainfall data was obtained from the Betoambari Bau-Bau Meteorological Station and the Sangia Nibandera Kolaka Meteorological Station during the 2009–2023 period, while clove crop productivity data was obtained from farmer surveys and reports from the Central Statistics Agency. The results of the study show that North Buton Regency has an average annual rainfall of 1,971 mm with slightly wet climate characteristics (Type C), while Kolaka Regency has an average annual rainfall of 1,973 mm with wet climate characteristics (Type B). Based on the evaluation of the suitability of the rainfall land, it is included in the S1 category (very suitable). Regression analysis showed that rainfall had a less significant relationship with the productivity of clove plants. The results of the regression analysis showed that the determination coefficient (R^2) of North Buton Regency was 12.59% and Kolaka Regency was 14.21%. Recommended management strategies to deal with rainfall anomalies in Kolaka Regency include improving drainage systems, soil management and conservation, and environmental sanitation. Meanwhile, in North Buton Regency, it includes the provision of irrigation, the use of mulch and the provision of organic matter.

Keywords: *Rainfall anomaly, clove productivity, management strategy and Southeast Sulawesi.*

1. INTRODUCTION

The agricultural sector is very vulnerable to climate change because it affects planting patterns, planting time, production, and yield quality. The climate variables that most affect plant growth are rainfall, temperature and air humidity [1]. The negative impact of climate change can reduce agricultural production by between 5 – 20% [2]. Changes in rainfall patterns, increasing frequency of extreme climate events, and rising air and sea level temperatures are serious impacts of climate change that affect the agricultural sector [3].

El Nino rainfall anomalies have an impact on water shortages due to low rainfall (below normal), on the other hand, La Nina rainfall anomalies have an impact on excess water due to high rainfall (above normal). These two extreme rainfall events result in droughts, floods, landslides and inundation, which have a further impact on the decline in agricultural production, including plantation crops such as cloves [4]. The rainfall pattern in Southeast Sulawesi is a monsoon-type region A pattern with the characteristic of the peak of the rainy season that occurs between December, January, February and the peak of the dry season occurs between August and September [5]. According to (Hadiwijaya; Manullang *et al.*) [6, 4] the quality of cloves grown in wet climates is lower than the quality of cloves grown in dry climates. In the process of growth, clove plants are greatly influenced by the ideal environmental conditions for clove cultivation. According to Djaenudin *et al.* [7] the ideal air temperature for the growth of clove plants ranges from 25º – 28ºC and the rainfall is 2000 – 3500 mm/year.

This study aims to analyze rainfall anomalies, analyze the impact of rainfall anomalies on clove crop productivity and determine clove crop management strategies for rainfall anomalies so that productivity increases again in two areas: North Buton Regency and Kolaka Regency.

II. METHODS

The research was conducted in two areas with different rainfall patterns in Southeast Sulawesi Province, precisely in North Buton Regency and in Kolaka Regency.

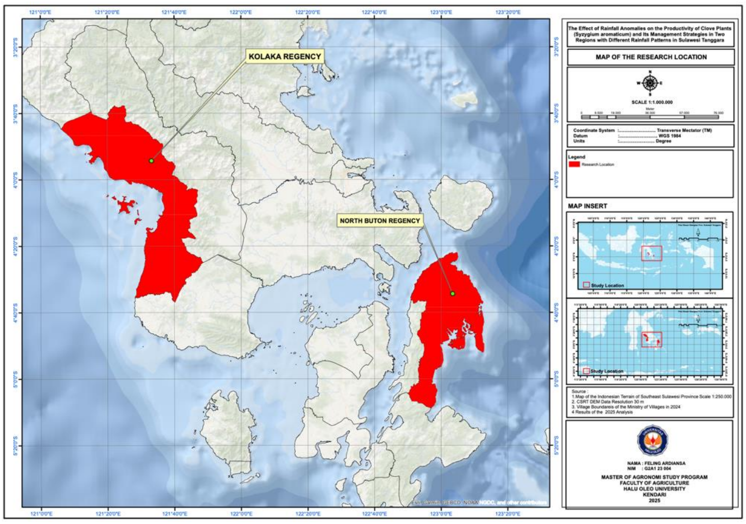

Fig 1. Map of the Research Location

The population of this study is a farming community that owns clove plants in Kolaka Regency and North Buton Regency. The sample of this study is clove farmers in 3 sub-districts and 18 villages in North Buton Regency and Kolaka Regency, Southeast Sulawesi Province. In determining the sample using *the snowball sampling* method, namely by selecting the initial sample, then asking to recommend others who will be the research sample. The number of respondents interviewed was three farmers in each village where the sample was located. The variables in this study are rainfall time series data for the 2009-2023 period sourced from the Betoambari and Sangia Nibandera Meteorological stations. Productivity data was obtained from the results of *Focus Group Discussions* (FGD), interviews and the Central Statistics Agency (BPS).

Analyzing Extreme Rainfall Anomalies

The quantitative descriptive analysis method in this study was carried out using the method of processing *rainfall time series* data of North Buton Regency and Kolaka Regency so that the pattern of rainfall intensity in the two regions was known.

Analysis of the Impact of Rainfall on Clove Plant Productivity

Regression analysis is used to predict the relationship between two functional variables, in this relation the non-free variable (Y) and the independent variable (X). Because it only uses one free variable, the regression used is a linear model with an equation:

$$Y = a + bX$$

Where:

Y : Clove Plant Productivity (tons/ha)

a dan b : Regression Coefficient

X : Annual Rainfall (mm)

The calculation of the coefficient values a and b, using the following formula:

$$a = \frac{(\sum X)(\sum X^2) - (\sum X)(\sum XY)}{n\sum X^2 - (\sum X)^2}$$

$$b = \frac{n\sum XY - (\sum X)(\sum Y)}{n\sum X^2 - (\sum X)^2}$$

Cofisien a can also be calculated using the formula: a = Y – bX,

Calculations are also carried out to determine the values of the correlation coefficient (r) and the determination coefficient (R^2); where the correlation coefficient (R) is used to determine the linear relationship between the free variable (X) and the non-free variable (Y), and the determination coefficient (R^2) to explain how much the independent variable is able to explain the non-free variable [8].

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

Recommendations for Clove Plant Management Strategies Against Rainfall Anomalies

The quantitative descriptive analysis method in this study is carried out by describing management strategies for rainfall anomalies and can be applied by clove farmers in Southeast Sulawesi so that the productivity of clove plants increases again.

III. RESULT AND DISCUSSION

Extreme Rainfall El Nino and La Nina in North Buton Regency

Annual rainfall data for the period 2009-2023 in the North Buton Regency area shows significant variations between dry, wet, and normal conditions. Based on the analysis, six years are classified as "Below Normal" (2009, 2012, 2015, 2016, 2019, and 2023), which indicates years with low rainfall conditions, or drier than average. The other five years fall into the "Above Normal" category (2010, 2013, 2017, 2021, and 2022), indicating years that tend to be wet with above-average rainfall. The remaining four years were in the "Normal" category (2011, 2014, 2018, and 2020), where annual rainfall was close to the normal average of 157.63 mm. These variations in rainfall patterns indicate the existence of annual climate and weather dynamics that affect the region, with conditions that fluctuate from year to year.

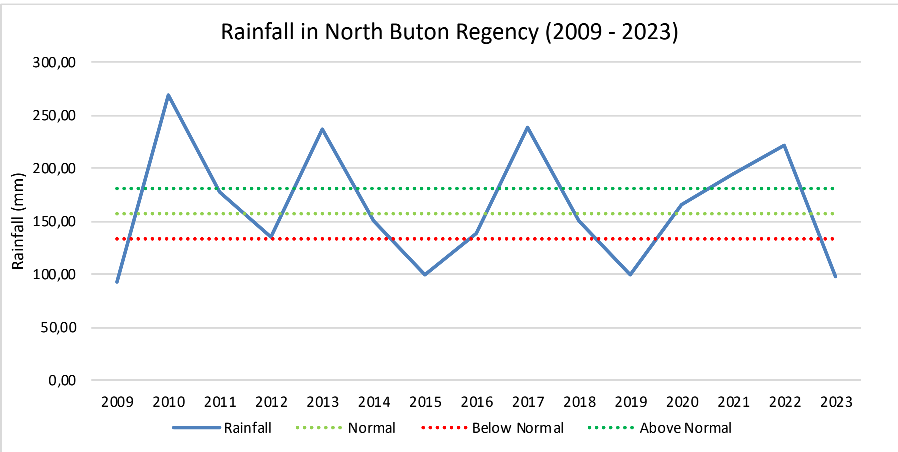

Fig 2. Annual Rainfall Distribution of North Buton Regency

Extreme Rainfall El Nino and La Nina in Kolaka Regency

Annual rainfall data for the period 2009 – 2023 in the Kolaka Regency area shows variations between dry, wet, and normal conditions. Based on the analysis, five years are classified as "Below Normal" (2011, 2014, 2016, 2018, and 2019), which indicates years with lower-than-average rainfall or drier conditions. The other five years fall into the "Above Normal" category (2010, 2013, 2015, 2021, and 2022), indicating wetter years with above-average rainfall. Meanwhile, five years are in the "Normal" category (2008, 2012, 2017, 2020, and 2023), which means that annual rainfall is close to the normal average.

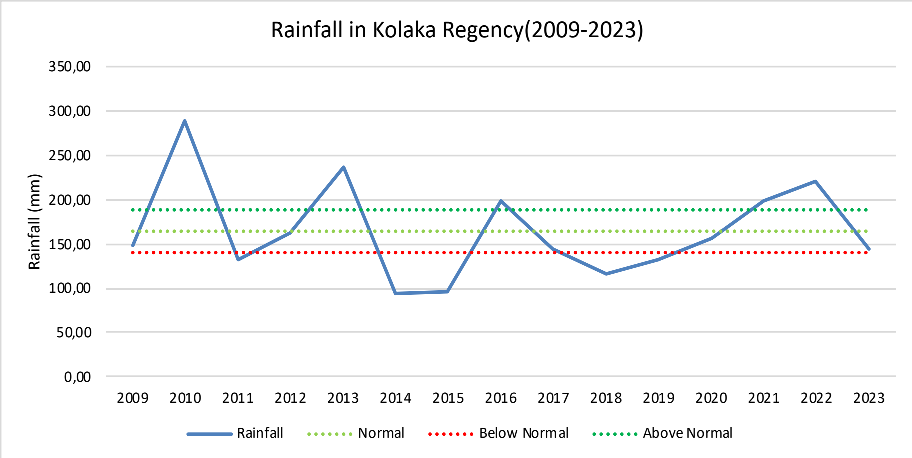

Fig 3. Annual Rainfall Distribution of Kolaka Regency

Based on the ENSO History score of the NINO Zone 3.4 (NOAA, 2023), an overview was obtained that from 2009 to 2023 El Nino events in Indonesia took place seven times, namely in 2014, 2015, 2016, 2018, 2019, and 2023, while La Nina occurred five times, namely in 2010, 2011, 2012, 2021, and 2022.

Table 1. Data Oceanic Nino Index (ONI): ENSO History Zone NINO 3.4 (NOAA, 2023)

Years	J	F	M	A	M	J	J	A	S	O	N	D
2009	**-0.84**	**-0,69**	**-0,54**	-0,21	0,03	0,12	0,27	0,47	0,37	*0,86*	*1,17*	*1,17*
2010	*1,16*	*0,92*	*0,87*	*0,70*	0,21	-0,26	**-0,66**	**-1,13**	**-1,47**	**-1,35**	**-1,43**	**-1,14**
2011	**-1,18**	**-1,07**	**-0,50**	**-0,75**	-0,42	-0,49	-0,40	-0,23	**-0,57**	**-0,69**	**-0,81**	**-1,01**
2012	**-0,92**	**-0,63**	**-0,68**	**-0,53**	-0,42	-0,34	-0,25	0,09	0,12	0,34	0,37	0,01
2013	-0,08	0,09	-0,49	-0,15	-0,22	-0,27	-0,17	-0,19	0,06	0,12	0,14	-0,30
2014	-0,32	-0,16	0,05	0,32	0,48	0,22	0,04	0,28	*0,53*	0,47	*0,73*	*0,75*
2015	*0,70*	*0,96*	*0,94*	*1,10*	*0,89*	*0,90*	*0,89*	*0,73*	*0,79*	*0,95*	*1,55*	*1,40*
2016	*1,26*	*1,37*	*1,2*	*0,75*	*0,56*	0,41	0,15	-0,01	-0,16	-0,40	-0,41	-0,06
2017	-0,07	-0,09	-0,06	0,11	0,19	0,44	0,23	0,09	-0,09	-0,13	-0,35	-0,39
2018	-0,20	-0,2	-0,18	0,05	0,13	0,24	0,22	0,47	0,46	*0,88*	*0,79*	*0,97*
2019	*0,83*	*0,85*	*0,87*	*0,61*	*0,62*	*0,69*	*0,73*	*0,62*	*0,57*	*0,84*	*0,73*	*0,85*
2020	*0,94*	*0,88*	*0,73*	*0,53*	0,04	0,15	0,05	-0,34	-0,43	**-0,71**	**-0,70**	**-0,85**
2021	**-1,00**	**-0,87**	-0,41	-0,18	-0,06	0,04	-0,13	-0,07	-0,42	**-0,57**	**-0,68**	**-0,76**
2022	-0,22	-0,23	**-0,65**	**-0,72**	**-0,86**	**-0,57**	**-0,88**	**-0,93**	**-1,01**	**-1,08**	**-0,90**	**-0,73**
2023	**-0,60**	**-0,52**	-0,14	0,3	0,33	*0,64*	*0,71*	*0,95*	*1,1*	*1,24*	*1,44*	*1,39*

Criterion:	ONI ≥ 0,5	El Nino
	ONI ≤ -0,5	La Nina
Information:		La Nina
		El Nino

El Nino (rainfall below normal) in North Buton Regency occurred six times, namely in 2009, 2012, 2015, 2016, 2019 and 2023 with the amount of annual rainfall of 139.63 mm/year each. Meanwhile, the intensity of La Nina events (rainfall above normal) occurred five times, namely in 2010, 2013, 2017, 2021 and 2022 with an annual rainfall intensity of 188.91 mm/year. In the Kolaka Regency area, El Nino events occurred five times, namely in 2011, 2014, 2015, 2018 and 2019 with a rainfall intensity of 139.56 mm/year. Meanwhile, the La Nina incident occurred five times, namely in 2010, 2013, 2016, 2021 and 2022 with a rainfall intensity of 188.81 mm/year. ENSO has a real influence on rainfall anomalies in Indonesia, especially during the dry season (June–August) and the transitional season (September–November) [9].

In the research area, namely in North Buton Regency and Kolaka Regency, from five years of rainfall irregularities that are more than normal conditions, three of them coincided with La Nina events in Indonesia, namely in 2010, 2021, and 2022. The most extreme La Nina event (above-normal rainfall) in North Buton Regency took place in 2022 with an annual rainfall of 2,662 mm/year, an increase from the normal state of 651 mm or 35.04% of normal conditions. Meanwhile, the most extreme La Nina incident in Kolaka Regency occurred in 2013 with an annual rainfall of 2,839 mm/year. In 2013, it was recorded that it was not a La Nina incident. The occurrence of above-normal rainfall (abundance) and the La Nina phenomenon give an idea that the occurrence of flooding in an area does not always coincide with the occurrence of La Nina, and the occurrence of La Nina does not always cause flooding or rainfall above normal [10].

Impact of Rainfall Anomalies on Clove Productivity

Data on rainfall and productivity of clove plants at the research site as shown in the following table:

Table 2. Rainfall and Productivity of Clove Plants in North Buton Regency and Kolaka Regency for the period 2009 – 2023

North Buton Regency			Kolaka Regency		
Years	Rainfall (mm) Period 2009-2023	Productivity (tons/ha)	Years	Rainfall (mm) Period 2009-2023	Productivity (tons/ha)
2009	1106	0.04	2009	1775	0,39
2010	3225	0.07	2010	3454	0,38
2011	2131	0	2011	1577	0,41
2012	1614	0.12	2012	1942	0,13
2013	2839	0.89	2013	2839	0,43
2014	1809	0.04	2014	1128	0,79
2015	1191	0.05	2015	1164	0,47
2016	1664	0.05	2016	2370	0,12
2017	2866	0.05	2017	1578	0,47
2018	1799	0.04	2018	1389	0,46
2019	1187	0.04	2019	1593	0,45
2020	1986	0,05	2020	1866	0,48
2021	2325	0,05	2021	2373	0,48
2022	2662	0,03	2022	2638	0,43
2023	1164	0,02	2023	1722	0,41

Source : Central Statistics Agency Data and Interview

Quantitatively, to find out how far El Nino affects the productivity of clove plants in North Buton Regency, a regression analysis was carried out to see the relationship between rainfall and plant productivity. Based on the results of regression analysis that saw the relationship between rainfall and clove plant productivity, the equation was obtained: y = 0.1198 + 0.000113 x with a correlation coefficient (r) value of 0.355. This equation illustrates that the higher the rainfall value (X), the higher the productivity of clove plants (Y).

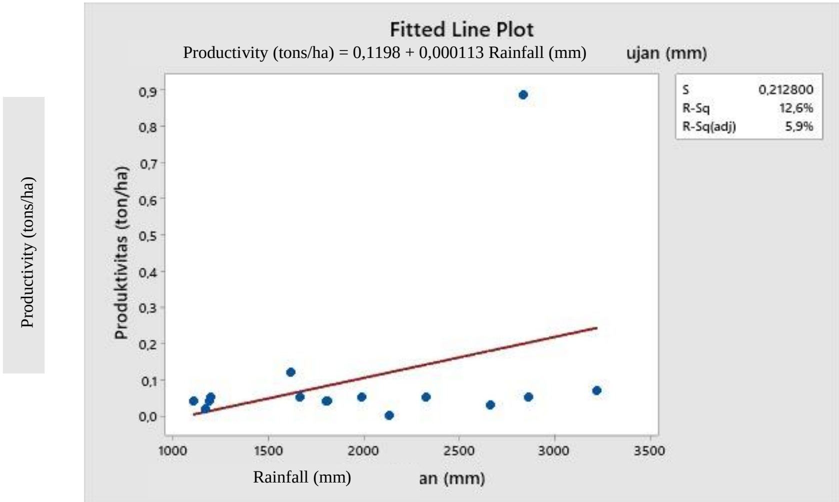

Fig 4. Graph of the Relationship between Rainfall and Clove Productivity in North Buton Regency

The value of the determination coefficient (R^2) of 12.59 %, shows that only 12.59% of productivity can be explained by rainfall. A low R^2 value indicates that other factors also have a major influence on productivity. The regression coefficient value shows that every increase in rainfall of 1 mm will increase the productivity of clove plants by 0.000113 tons/ha.

Sufficient rainfall helps to maintain soil moisture, which is essential for the physiological processes of the plant, including flowering and fruit formation. Additionally, the even distribution of rainfall can increase the availability of nutrients in the soil, allowing plants to absorb nutrients more efficiently, ultimately contributing to increased productivity.

Quantitatively, to find out how far the influence of rainfall on the productivity of clove plants in Kolaka Regency, a regression analysis was carried out to see the relationship between rainfall and plant productivity. Based on the results of regression analysis that saw the relationship between rainfall and clove plant productivity, the equation was obtained: y = 0.5925 + 0.000088 x with a correlation coefficient (r) value of 0.3771. This equation illustrates that the higher the rainfall value (X), the lower the productivity of clove plants (Y).

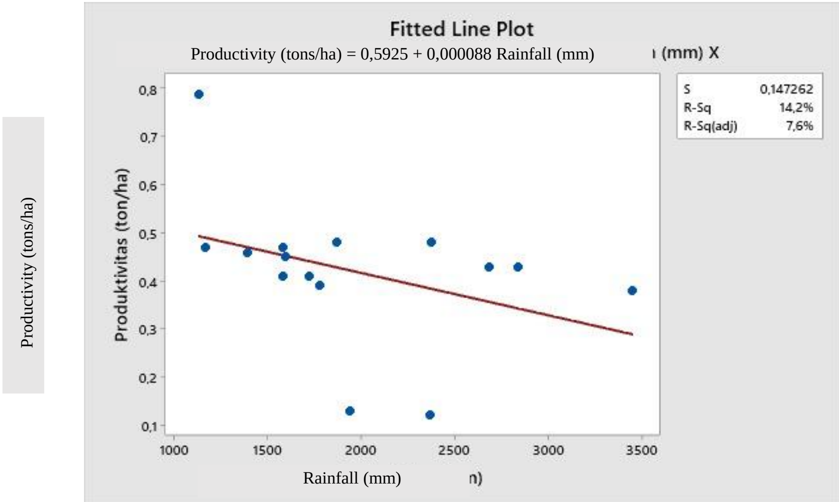

Fig 5. Graph of the Relationship between Rainfall and Clove Productivity in Kolaka Regency

The value of the coefficient of determination (R^2) of 14.21% shows that only 14.21% of productivity can be explained by rainfall. A low R^2 value indicates that other factors also have a major influence on productivity. The regression coefficient value shows that every increase in rainfall of 1 mm will decrease the productivity of clove plants by 0.000088 tons/ha.

Clove Plant Management Strategy in Kolaka Regency

The form of management as a form of adaptation strategy to ikim anomalies to increase the productivity of clove plants is as follows:

Improvement of drainage system

Drainage system improvement serves to control surface water needs by taking measures to improve waterlogging and flooding so that there is no accumulation of groundwater, lowering the groundwater level to the ideal level [11]. Soil tillage and soil drainage indirectly affect plant physiology through root respiration mechanisms. Drainage conditions in the inhibited planting area can cause soil conditions to become saturated with water and the occurrence of oxygen level deficits which have an impact on nutrient absorption by plants [12].

Soil Management and Conservation

The application of good soil management techniques such as the application of organic matter, the return of litter and/or plant residues to the soil, proper tillage, and weed control can improve soil fertility and structure [13]. Reducing the danger of erosion can be done by improving the condition of the land surface such as a terrace system in the form of individual terraces on clove plants, stair terraces or bench terraces. Likewise, planting ground cover plants can be carried out in order to protect the soil from direct rainwater and reduce and even reduce surface flow water so that it can minimize soil erosion due to erosion [14]. Dense soil conditions need to be managed appropriately so that plant growth is not disturbed and crop yields are not disturbed [15].

Environmental Sanitation

Efforts to manage the environmental sanitation of clove plants can be carried out by cleaning weeds and plant residues that can be a place for pests and diseases to develop, pruning dead or diseased branches to prevent the spread of pathogens. cultivate good soil to improve aeration and drainage, thereby reducing the risk of root disease attacks [16].

Clove Plant Management Strategy in North Buton Regency

Irrigation Provision/Water Management

Clove farmers in North Buton Regency in providing irrigation as water management use the Rainwater Harvesting system so that the needs of clove plants are met. Rainwater harvesting has great potential to be developed in meeting water limitations for plants [17]. Abundant rainwater during the rainy season is not fully absorbed by the soil. Rainwater that cannot be absorbed by the soil will simply overflow. If this runoff water is stored in a reservoir, then the water can be used for irrigation water [18]. Proper and efficient use of rainwater for irrigation can make aquatic solutions so that drought does not become a factor that interferes with the growth of plantation crops [19]. A proper and efficient rainwater harvesting system can save water needs for crops so that soil moisture and plant productivity increase [20].

Application of Mulch

The proper use of mulching materials results in a more balanced microclimate, as well as better heat and water management; this significantly increases the number of soil microbes and their activity also increases [21] Mulching the soil surface during the rainy season prevents soil surface erosion [22]. The ability of mulch to suppress weed growth and reduce soil erosion can be improved by paying attention to the intensity of the naming system [23]. In the dry season, it will retain the sun's heat on the upper soil surface. Suppression of evaporation results in relatively low and moist temperatures in the mulched soil [24]. Climate factors determine the balance between the entry and exit of C and N in the soil system [25]. Mulching can inhibit weed growth and can increase soil fertility, especially for organic mulch [26]. The use of mulch provides various advantages, both from the biological, physical and chemical aspects of the soil. The application of the right mulching technique can be an effective solution where existing rainfall can be held back into small irrigation water so that it can reduce drought and soil degradation [27]. The type of mulch material greatly affects water retention and water utilization in the soil during crop production [28]. Mulching with waterproof materials (e.g., plastic films) minimizes losses caused by evaporation; however, incoming rainfall cannot be utilized in the root zone [29].

Organic Matter Provision

The application of organic matter to certain soils can increase soil fertility in certain land units [30]. Organic matter is able to improve aeration, root penetration, water absorption and reduce soil surface movement. Porous soil causes plant roots to easily penetrate into the soil [31]. Soil organic matter, its stable components (humic substances) and its temporary components are able to increase the availability and yield of nutrients by high-level plants as well as nutrient storage and availability in the soil [32]. Soil organic matter provides important ecosystem services and is at the core of some of the major challenges facing humans, including mitigating climate change and maintaining food and fiber production [33].

IV. CONCLUSION

Data from 2009 to 2023 shows that North Buton Regency and Kolaka Regency experience unstable rainfall patterns due to the influence of El Nino and La Nina phenomena. El Niño that occurs in certain years causes very low rainfall, while La Nina increases rainfall to the extreme. This variation causes clove production to be unstable, as the plant needs steady rainfall to develop properly.

In North Buton Regency, the higher the rainfall, the higher the productivity of clove plants as shown by the correlation coefficient value (R) of 0.355 with a determination coefficient of (R2) of 12.59%. Meanwhile, in Kolaka Regency, the higher the rainfall, the lower the productivity of clove plants as shown by the value of the correlation coefficient (r) of 0.3771 with a determination coefficient of (R2) of 14.21%.

To reduce the negative impact of rainfall anomalies on clove plants, several management strategies that can be applied in Kolaka Regency are improving the drainage system, soil management and conservation (using mulch, making terraces and providing organic matter) and improving environmental sanitation. Meanwhile, in North Buton Regency, several management strategies are recommended, namely the provision of irrigation or water management, the use of mulch and the provision of organic matter.

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