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Study on Rainfall Effects on Corn (*Zea mays* L.) Productivity in Ngawi Regency

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***Abstract*— *The demand for corn in Indonesia is currently quite high, in line with the growing population and the increasing need for corn to meet the feed industry. Corn productivity has increased due to the expansion of land area and has not yet reached its yield potential due to climate change. Climate is a determining factor for the success of crop cultivation, thus it is necessary to study the relationship between climate elements and their effects on corn productivity in Ngawi Regency. The study was conducted from September to November 2022 using the survey method. The location was determined using purposive sampling technique directly determined by the researchers based on the corn production centers in Ngawi Regency. The chosen research locations were Pitu, Bringin, and Kendal Subdistricts. The climate classification in Pitu Subdistrict, Bringin Subdistrict, and Kendal Subdistrict has climate types D, C, and C, respectively. Correlation test results show that in Pitu Subdistrict, there is no significant correlation between rainfall intensity, rainy days, wet months, and dry months with corn productivity. Rainy days show a significant positive correlation with corn productivity in Bringin Subdistrict, while in Kendal Subdistrict, rainfall intensity and rainy days show a significant negative correlation with corn productivity.*

***Keywords*— rainy days, rainfall intensity, corn, climate change.**

I. INTRODUCTION

Corn is a strategic and economically valuable commodity as a primary source of carbohydrates and protein after rice. Corn also serves as raw material for the feed and household industries. Corn is a strategic crop to be cultivated in various regions. As a primary food source, corn has become a major commodity after rice (Ginting, Kuswardani, and Azwana 2012). The demand for corn in Indonesia is currently quite high, in line with the growing population and the increasing need for corn to meet the feed industry. National corn production in Indonesia has been continuously increasing every year.

This increase is due to the expansion of land area, thus corn productivity increases with the expansion of land area. However, the increase in corn productivity has not yet reached its optimal productivity potential of 10 – 11 tons ha^{-1}, while corn productivity in Indonesia is only 5 – 6 tons ha^{-1} (Nurdin et al. 2021). Factors affecting crop productivity can be broadly categorized into internal and external factors. External factors can be caused by rainfall, temperature, sunlight intensity, and air humidity. These climate factors often change due to global warming (Naura and Riana 2018).

Lack of information about climate change can cause corn production to decline or even result in crop failure. Climate change can affect corn productivity. One of the impacts of climate change is the change in rainfall intensity. Rainfall plays a role in water supply, especially in rainfed and dry lands. Excessive rainfall can increase the amount of surface water, which can affect plant growth (Herlina and Prasetyorini 2020). Therefore, research is needed on the relationship between climate elements and their impact on corn productivity, especially in Ngawi Regency, which has not been widely studied.

II. MATERIALS AND METHODS

The study was conducted from September to November 2022 in several corn production centers in Ngawi Regency. The study used a survey method by collecting field observation data and secondary data on corn production in Ngawi Regency and climate elements data consisting of rainfall intensity, rainy days, wet months, and dry months. The research location was determined by purposive sampling based on the corn production centers in Ngawi Regency. The chosen research locations were Pitu Subdistrict, Kendal Subdistrict, and Bringin Subdistrict. The data used included land area data, production data, rainfall intensity, rainy days, wet months, and dry months in the research area over the past 10 years, from 2011 to 2020. The data obtained were then analyzed for correlation to determine the relationship between the climate elements studied and corn productivity. The correlation analysis results will yield a correlation coefficient (r) value between -1 or 1. Interpretation of the correlation coefficient value is as follows:

0.00 – 0.199 = very low

0.20 – 0.399 = low

0.40 – 0.599 = moderate

0.60 – 0.799 = strong

0.80 – 1.000 = very strong

Multiple regression analysis was also performed to determine the effect of rainfall intensity, rainy days, wet months, and dry months on corn productivity in the three subdistricts of Ngawi Regency. The multiple linear regression equation generally used is based on Mulyani et al. (2019), which is:

Y=A+B1X1+B2X2+B3X3+B4X4

Explanation:

Y = dependent variable (corn production)

X1 = variable rainfall intensity

X2 = variable rainy days

X3 = variable wet months

X4 = variable dry months

A = constant

B1 = coefficient of rainfall intensity variable

B2 = coefficient of rainy days variable

B3 = coefficient of wet months variable

B4 = coefficient of dry months variable

III. RESULTS AND DISCUSSION

Corn Productivity

Corn productivity in Pitu Subdistrict was highest in 2016 at 7901 kw ha-1, while the lowest productivity occurred in 2011 at 5684 kw ha^{-1} (Table 1). Corn productivity in Bringin Subdistrict was highest in 2015 at 7990 kw ha^{-1}, while the lowest productivity occurred in 2011 at 4947 kw ha^{-1} (Table 2). Corn productivity in Kendal Subdistrict was highest in 2015 at 8936 kw ha^{-1}, while the lowest productivity occurred in 2011 at 5667 kw ha^{-1} (Table 3).

Rainfall Intensity

The highest rainfall intensity in Pitu Subdistrict occurred in 2013, amounting to 2560 mm year-1, while the lowest rainfall intensity occurred in 2019, amounting to 1107 mm year-1 (Table 1). The highest rainfall intensity in Bringin Subdistrict occurred in 2016, amounting to 2665 mm year-1, while the lowest rainfall intensity occurred in 2018, amounting to 1476 mm year-1 (Table 2). The highest rainfall intensity in Kendal Subdistrict occurred in 2011, amounting to 5288 mm year^{-1}, while the lowest rainfall intensity occurred in 2014, amounting to 1807 mm year^{-1} (Table 3).

Rainy Days

The highest number of rainy days in Pitu Subdistrict occurred in 2016, amounting to 159 days year^{-1}, while the lowest number of rainy days occurred in 2011, amounting to 81 days year^{-1} (Table 1). The highest number of rainy days in Bringin Subdistrict occurred in 2017, amounting to 140 days year^{-1}, while the lowest number of rainy days occurred in 2013, amounting to 84 days year^{-1} (Table 2). The highest number of rainy days in Kendal Subdistrict occurred in 2011, amounting to 207 days year^{-1}, while the lowest number of rainy days occurred in 2013, amounting to 110 days year^{-1} (Table 3).

Wet Months

The highest number of wet months in Pitu Subdistrict occurred in 2013, amounting to 9 months, while the lowest number of wet months occurred in 2018, amounting to 3 months (Table 1). The highest number of wet months in Bringin Subdistrict occurred in 2016, amounting to 10 months, while the lowest number of wet months occurred in 2018, amounting to 5 months (Table 2). The highest number of wet months in Kendal Subdistrict occurred in 2011 and 2016, amounting to 12 months, while the lowest number of wet months occurred in 2019, amounting to 5 months (Table 3).

Dry Months

The highest number of dry months in Pitu Subdistrict occurred in 2014, 2015, and 2019, amounting to 6 months, while the lowest number of dry months occurred in 2013 and 2017, amounting to 2 months (Table 1). The highest number of dry months in Bringin Subdistrict occurred in 2018, amounting to 7 months, while the lowest number of dry months occurred in 2016, amounting to 2 months (Table 2). The highest number of dry months in Kendal Subdistrict occurred in 2018 and 2019, amounting to 6 months, while the lowest number of dry months occurred in 2011 and 2016, with no dry months recorded (Table 3).

Table 1. Data on corn productivity and climate elements in Pitu Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	56.84	1781	81	6	3
2012	62.58	1702	99	7	4
2013	58.48	2560	129	9	2
2014	61.62	1349	96	6	6
2015	75.33	1550	95	5	6
2016	79.01	1458	159	7	3
2017	77.69	1814	124	8	2
2018	73.26	1304	101	3	7
2019	72.38	1107	100	4	6
2020	70.02	1759	122	7	3

Source: BPS Ngawi (2020) and BMKG Jatim (2020)

Table 2. Data on corn productivity and climate elements in Bringin Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	49.47	1603	87	7	5
2012	66.11	1763	96	7	5
2013	56.68	2388	84	8	4
2014	77.03	2319	101	7	4
2015	79.90	2087	133	8	3
2016	79.27	2665	115	10	2
2017	74.92	2097	140	8	3
2018	72.72	1476	103	5	7
2019	77.81	1860	120	6	5
2020	71.88	2507	138	8	3

Source: BPS Ngawi (2020) and BMKG East Java (2020)

Table 3. Data on corn productivity and climate elements in Kendal Subdistrict, Ngawi Regency, 2011 – 2020

Year	Productivity (kw ha^{-1})	Rainfall Intensity (mm)	Rainy Days (days)	Wet Months (months)	Dry Months (months)
2011	56,67	5288	207	12	0
2012	64,79	2223	175	6	5
2013	58,31	3469	172	9	3
2014	87,34	1807	121	9	3
2015	89,36	2694	137	7	4
2016	78,79	3645	189	12	0
2017	76,35	2622	143	7	4
2018	72,14	2063	121	6	6
2019	72,47	1857	110	5	6
2020	70,79	2661	144	8	4

Source: BPS Ngawi (2020) and BMKG East Java (2020)

Table 4. Correlation coefficients (r) of rainfall intensity, rainy days, wet months, and dry months with corn productivity in three subdistricts of Ngawi Regency

Corn Productivity in Subdistricts	Rainfall Intensity	Rainy Days	Wet Months	Dry Months
Pitu	-0.464	0.470	-0.262	0.166
Bringin	0.319	0.702*	0.126	-0.332
Kendal	-0.535	-0.574	-0.177	0.144

Note: * = significant correlation

Table 5. R^2 values of the effect of rainfall intensity, rainy days, wet months, and dry months on corn productivity in three subdistricts of Ngawi Regency

Subdistrict	R^2 Value
Pitu	0.62
Bringin	0.57
Kendal	0.80

Correlation of Corn Productivity and Climate Elements

Rainfall intensity and rainy days in Pitu Subdistrict have a moderate relationship with corn productivity, with values of r = -0.464 and r = 0.470. Wet months and dry months have a low relationship with values of r = -0.262 and r = 0.166. Rainfall intensity and dry months in Bringin Subdistrict have a low relationship with corn productivity, with values of r = 0.319 and r = -0.332, while wet months have a very low relationship with a value of r = 0.126. Rainy days, however, have a strong relationship with a value of r = 0.702. Rainfall intensity and rainy days in Kendal Subdistrict have a strong relationship with corn productivity, with values of r = -0.535 and r = -0.574. Wet months and dry months have a low relationship with values of r = -0.177 and r = 0.144 (Table 4).

A negative correlation means that the climate element decreases corn productivity, while a positive correlation means that the climate element increases corn productivity. Rainfall intensity decreases corn productivity in Pitu and Kendal Subdistricts but increases corn productivity in Bringin Subdistrict. This is possibly due to excessive water availability causing waterlogging, which affects nutrient leaching, while increased production indicates sufficient water availability and good soil conditions. This aligns with Suciantini (2015), who stated that increased rainfall intensity in a region can potentially cause floods that trigger erosion and nutrient leaching. Conversely, a decrease in rainfall intensity can potentially cause drought, affecting plant growth (Wokanubun, Ririhena, and Wattimena 2020). Besides drought, another impact of climate change is prolonged rainfall, which can disrupt corn plant growth. Corn is not tolerant of waterlogging as it interferes with plant aeration and respiration (Hermawan et al. 2014).

Corn does not require much water and can be planted in various seasons. Water availability in the field must be adjusted to the plant's needs to avoid excess or deficiency. This aligns with Rusastra et al. (2004), who stated that corn is a plant that absorbs water in small amounts and can be planted during the dry season. Corn has a high ability to absorb water in the soil, balancing the amount of evaporated water (Chagwiza et al. 2020). Moreover, corn requires rainfall ranging from 85 to 200 mm per month (Asriani and Ma'Mun 2019). If the rainfall in a region meets the corn plant's needs, corn planting can be done 2 to 3 times a year (Hikami, Arifianto, and Giarno 2023).

Regression Analysis of Corn Productivity with Climate Elements

The R2 value indicates the influence of rainfall intensity, rainy days, wet months, and dry months on corn productivity in the research area (Table 5). The R2 value in Pitu Subdistrict is 0.62, indicating that 62% of corn productivity is influenced by climate elements. In Bringin Subdistrict, the R2 value is 0.57, indicating that 57% of corn productivity is influenced by climate elements. In Kendal Subdistrict, the R2 value is 0.80, indicating that 80% of corn productivity is influenced by climate elements.

The regression analysis results for rainfall on corn productivity in Pitu Subdistrict yield the equation: $Y = 7035 - 0.008\,\text{Rainfall Intensity} + 0.026\,\text{Rainy Days} - 2.24\,\text{Wet Months} - 0.83\,\text{Dry Months}$, This equation shows that an increase in rainfall intensity by 1 mm per year will decrease corn productivity by 0.008 quintals, an increase in rainy days by 1 day will increase corn productivity by 0.026 quintals, an increase in wet months by 1 month will decrease corn productivity by 2.24 quintals, and an increase in dry months by 1 month will decrease corn productivity by 0.83 quintals.The regression analysis results for rainfall intensity and rainy days on corn productivity in Bringin Subdistrict yield the equation: $Y = -0.34 + 0.001\,\text{Rainfall Intensity} + 0.038\,\text{Rainy Days} - 1.51\,\text{Wet Months} + 2.49\,\text{Dry Month}$, This equation shows that an increase in rainfall intensity by 1 mm per year will increase corn productivity by 0.001 quintals, an increase in rainy days by 1 day per year will increase corn productivity by 0.038 quintals, an increase in wet months by 1 month will decrease corn productivity by 1.51 quintals, and an increase in dry months by 1 month will increase corn productivity by 2.49 quintals in Bringin Subdistrict.

The regression analysis results for rainfall intensity on corn productivity in Kendal Subdistrict yield the equation: $Y = 25764 - 0.008\,\text{Rainfall Intensity} - 0.29\,\text{Rainy Days} - 8.09\,\text{Wet Months} - 15.06\,\text{Dry Months}$, This equation shows that an increase in rainfall intensity by 1 mm per year will decrease corn productivity by 0.008 quintals, an increase in rainy days by 1 day per year will decrease corn productivity by 0.29 quintals, an increase in wet months by 1 month will decrease corn productivity by 8.09 quintals, and an increase in dry months by 1 month will decrease corn productivity by 15.06 quintals in Kendal Subdistrict.

An increase in rainfall intensity in Pitu and Kendal Subdistricts can decrease corn productivity, while an increase in rainfall intensity in Bringin Subdistrict can increase corn productivity. This is likely influenced by soil conditions, elevation, variety used, cultivation techniques, and planting time differences among farmers, indicating other factors affecting corn productivity. This aligns with Nurdin et al. (2021), who stated that water deficit or excess in corn can reduce yield, especially during the grain-filling phase. Planting time needs to be considered, especially during the rainy or dry season, to meet the corn plant's needs. Increased rainfall intensity increases the amount of water received by the soil surface, potentially causing waterlogged soil, affecting soil aeration. This aligns with Santoso and Layli (2011), who stated that high rainfall can cause floods, making the soil waterlogged, leading to root rot. This can cause an earlier harvest time to avoid crop failure.

IV. CONCLUSIONS

Climate elements affect corn productivity in the three subdistricts of Ngawi Regency. Increased rainfall intensity can decrease corn productivity in Pitu and Kendal Subdistricts, while a decrease in rainy days can increase corn productivity in Bringin Subdistrict. The number of wet and dry months does not affect corn productivity in the three subdistricts of Ngawi Regency.

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