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Rainfall and Temperature Projection Analysis and Their Relation to The Potential Harvest Amount of Maize (Zea mays L.)

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Abstract— *Maize is one of the commodities used as a source of food for the Indonesian people besides rice. Maize is also often used as an industrial raw material, food or feed. Maize productivity in Indonesia in 2023 decreased by 0.07 tons/ha or 0.5% compared to the productivity in 2022 of 14.08 tons/ha. East Java Province is the region with the highest production in Indonesia. East Java contributes about 25.60 percent of Indonesia's total production. One of the problems in corn production is climate change. Climate change affects the agricultural sector with extreme changes in rainfall and temperature. Rainfall and temperature can affect evapotranspiration in determining crop water requirements. Water requirements can affect the quality and quantity of crop production. Therefore, it is necessary to conduct strategic mitigation and adaptation based on the possibility of climate change that occurs in the future using climate projection scenarios. The climate scenario used is Representative Concentration Pathways (RCP). The purpose of this study is to project the increase in rainfall and temperature in Tuban district and Malang district based on the RCP scenario and its relationship with the potential yield of maize. This research was conducted in December - January 2025. The research locations taken were Tuban Regency and Malang Regency. The research was conducted using descriptive analysis method. The research location used purposive sampling method based on consideration according to the required criteria, namely lowlands and midlands. The data used in this study are monthly rainfall projection data, minimum temperature, maximum temperature and average temperature. In addition, there are also longitude and latitude data, root depth, deplection fraction, pan evaporation, crop coefficient and correction factor. Climate projection scenario data is used with the Representative Concentration Pathways (RCP) 4.5 and 8.5 scenario models REG CM 4 and CSIRO MK 3.6. The results showed that rainfall and temperature projections as well as irrigation needs and potential crop yields showed that projections using RCP 8.5 showed a higher increase compared to RCP 4.5 which tended to experience stable fluctuations. In the rainfall projection, Malang Regency tends to experience a higher increase than Tuban Regency. Meanwhile, the temperature projection of Tuban Regency tends to show a higher increase compared to Malang Regency. Irrigation water demand in both regions tends to increase in August and September. Meanwhile, potential crop yields in both regions are projected to decline where Tuban Regency is more vulnerable to a higher yield decline compared to Malang Regency due to lower rainfall.*

Keywords— ***Climate projection, Maize, Climate change, Irrigation water demand, Potential crop yield.***

I. INTRODUCTION

Climate change is an issue that occurs almost all over the world. Climate change is caused by increasing greenhouse gas emissions, triggering global warming (Widiarta, 2016). The impact of climate change is greater in tropical areas, especially Indonesia, such as global temperature increases, rising sea levels, shifting rainfall patterns and causing increased extreme rainfall[1]. This phenomenon has a major impact on several sectors in Indonesia, especially the agricultural sector. The impact of changes in rainfall patterns and temperatures that most affect plant productivity. Changes in rainfall patterns and temperatures can result in increased pest and disease attacks, which can reduce farmer productivity and income. Food crops are one of those that have an impact both in terms of quality and quantity, especially corn. Corn is one of the staple commodities used as a source of food for the Indonesian people besides rice. Corn is a plant that is included in the cereal group which has economic and strategic value so that there is an opportunity to be developed as a source of carbohydrates after rice [1]. Feed and industrial needs dominate around 50% of national corn needs, so that corn production must be increased both through increasing corn productivity and expanding planting areas. According to the Center for Agricultural

Data and Information Systems (2024), the volume of corn exports in Indonesia decreased in 2022 by 237,386 tons and in 2023 by 180,257 tons, while the volume of imports increased in 2022 by 1,311,064 tons and in 2023 by 1,354,187 tons. Corn plant productivity in Indonesia in 2023 decreased by 0.07 tons/ha or 0.5% compared to productivity in 2022 of 14.08 tons/ha (Directorate General of Food Crops, 2023). East Java Province is the region with the highest production in Indonesia. East Java contributes around 25.60 percent of the total corn production in Indonesia [1]. One of the regions with the largest production is Tuban Regency is also a center for corn production in East Java Province and is included in the lowland area. In addition, Malang Regency is one of the corn producing areas in the middle plains. In the cultivation of food crops, especially corn, there are several environmental factors that play a major role in plant growth, such as altitude. Corn plants are plants that are easily adaptable and can grow in lowlands to highlands. Different altitudes will trigger differences in quality and quantity in plants and affect plant growth and development [1].

Corn is a plant that is sensitive to high and extreme temperatures, especially during flower formation [2]. These extreme temperature changes can result in a decrease in the quality and quantity of the corn plants produced. Temperature and rainfall are factors that can affect evapotranspiration. Evapotranspiration in agriculture can function in determining the water needs of plants or determining planting patterns that are appropriate for the area to be planted. This water requirement can affect the quality and quantity of plant productivity [3]. This water requirement calculation is used to plan the amount of water needed by plants as well as the right time and planting period according to the plant growth phase. Therefore, in dealing with these problems, strategic mitigation and adaptation are needed based on the possibility of climate change that will occur in the future using climate projection scenarios. Scenarios allow for analyzing and studying the consequences faced in the long term and exploring the possibilities that may occur in the future [4]. In this case, scenarios are carried out to predict climate change that will occur in the future. In the process of predicting climate, several experts use a climate prediction model called climate data projection or Climate Projection Modeling [5]. This model aims to predict the possibilities that will occur in the future and can analyze the possible causes. One of the climate models that is often used is the Representative Concentration scenario Pathways. RCP focuses on atmospheric greenhouse gas concentrations, energy use, radiative effects, land use and temperature anomalies based on time. This scenario also includes 4 trends based on the development of greenhouse gas emissions, namely a scenario with close mitigation (RCP 2.6), an intermediate scenario (RCP 4.5 and RCP6.0) and a scenario with high greenhouse gas emissions (RCP8.5) [6]. This study was conducted to project increased rainfall and temperature using two different scenarios in corn production areas representing lowlands and midlands. The scenarios used are RCP 4.5 as a pessimistic scenario (intermediate scale) and RCP 8.5 as an optimistic scenario (high scale).

II. LITERATURE REVIEW

A. Corn Plant

Corn (Zea mays L.) is a type of plant that is classified as a grain food crop that also comes from the grass family and is one of the important carbohydrate-producing plants in the world besides rice and wheat (Sulaiman et al., 2018). Corn is a plant that has one house (monoecious) because the location of female flowers with male flowers is separate but still on the same plant. Corn is a C4 plant that can adapt to growth limiting factors and corn is also susceptible to low sunlight because it can affect the growth of corn plants (Syafruddin et al., 2014). Corn plants have three types of roots, namely seminal roots, adventitious roots and hook roots (Fiqriansyah et al., 2021). Seminal roots are roots that develop from the radicle and embryo.

Corn plants have stem segments with variations of 10-40 segments. The stem segments are usually round, flat at the bottom and cylindrical at the top and have no branches. Corn stalks are about 2-2.5 meters long and have several types and varieties (Sulistiana and Ilyas, 2022). Corn plant node nodes have shoots that can develop into cobs, while the top two shoots will develop into cobs. Corn stalks have 3 main tissues including skin tissue (epidermis), stem center (pith) and vascular tissue (vascular bundles) (Fiqriansyah et al., 2021). Corn has strong stems and many layers of thick-walled sclerenchyma tissue under the stem and around the vascular bundles. The thickness of the skin varies which can be used as a selection of plant tolerance to stem lodging.

Corn plants are plants that originate from tropical areas. Corn usually grows in areas located between 0o-50o North Latitude to 0o 40o South Latitude. These areas are areas with moderate to wet subtropical climates. Corn grows in places with full sunlight. Corn can grow in all seasons depending on the availability of sufficient water. The rainfall needed by corn plants to grow is between 200-800 mm per month (Riwandi et al., 2014). The best time to plant corn is at the start of the dry season and at the beginning of the rainy season. The appropriate altitude for corn growth is between 0-1300 meters above sea level with an optimal temperature of 23-27 oC (Hitijahubessy et al., 2016). Corn growth really needs full sunlight because shaded corn plants can inhibit growth and the seeds produced are not good or cannot even form cobs. Corn plants in their growth require an average temperature of 24 OC with a minimum temperature between 8-10 OC and a maximum temperature above 40 OC. At the time of seed germination, a temperature of 25 OC is a temperature that can accelerate the process, while temperatures above 40 OC can inhibit plant germination.

B. Climate Change and Its Impact on Increases and Decrease in Rainfall and Temperature

Climate change is one of the phenomena that is currently threatening human life. Over the last century, the phenomenon of global warming has become an important issue, especially in global governance or development policies (Rasmikayati and Djuwendah, 2015). Global warming occurs due to human activities. Human activities such as the use of fuel, natural gas, coal and petroleum. For example, the use of fuel in vehicles that can produce carbon dioxide or other gases such as Methane ($CH4$), water vapor ($H2O$), Nitrous Oxide ($N2O$), Chloro Fluoro Carbon (CFC), Ozone ($O3$) which are called greenhouse gases (Ainurrohmah and Sudarti, 2022). This phenomenon occurs due to increased greenhouse gas emissions into the atmosphere. These greenhouse gases can trap the sun's heat in the atmosphere and can cause climate instability and increased temperatures (Hariyono and Rochadi, 2024). The continuation of greenhouse gases can cause long-term changes in climate conditions and further warming. These impacts can be widespread and increasingly severe so that they cannot be controlled by humans or ecosystems (UNCTAD, 2016). Extreme climate conditions have increased, marked by increased climate variability in the last thirty years.

Climate change will continue to increase if human activities that cause global warming cannot be reduced. Climate change is already in a critical phase. Where in this phase it is likely to be very difficult to overcome the impacts of climate change. Climate change can have an impact on several aspects of human life. The agricultural sector is one of the sectors affected because it is the source of the economy that contributes the most to some of the Indonesian people (Syakir and Surmaini, 2017). Climate is the most influential factor in agriculture. Climate change can have an impact on plant physiology which also affects plant growth and production (Timotiwu et al., 2021). This impact is caused by the highest increase in temperature so that the photosynthesis process can be disrupted. Climate change can have an impact on increasing extreme climates such as the frequency of El-Nino and La-Nina which also increases. El-Nino can cause drought due to the long dry season, while La Nina has an impact with an increase in high rainfall which can result in excess water or flooding (Widiarta, 2016). Climate change also affects the characteristics of rain and the duration of the rainy season which is getting shorter, while the dry season period is getting longer. This has an impact on the number of rainy days decreasing and the intensity of rainfall and maximum daily rainfall increasing (Yasa et al., 2024).

C. The Effect of Rainfall and Temperature on Corn Plant Productivity

Climate is one of the important resources for plant productivity. Climate elements that can affect plant productivity are rainfall and temperature. Increased temperature and rainfall due to global warming can threaten food security and agricultural production (Li et al., 2019). The rainfall conditions in an area are an important factor in plant growth. Rainfall is the accumulation of rainwater that falls in a period with a certain time unit (Ruswanti, 2020). Unstable or changing rainfall can cause problems such as extreme rainfall can cause flooding or low rainfall can experience drought. The impact of climate change such as changes in unpredictable rainfall has a major impact on the agricultural sector. This is because the agricultural sector is very dependent on water, especially rainwater (Ruminta, 2016).

This impact can also occur in plant metabolism, potentially leading to decreased production or crop failure.

The variability of rainfall in Indonesia results in shifts in the rainy and dry seasons. The increase in the frequency of severe climate change can cause an increase in abiotic and biotic stress on plants (Syakir and Surmaini, 2017). Drought is the leading cause of crop failure due to climate change. The impact of climate change is also directly seen from the increasing attacks of pests and diseases. Armyworm (Spodoptera frugiperda) is one of the pests that often attacks corn plants in high rainfall conditions. Corn growth is greatly influenced by rainfall, especially if there is no adequate drainage. This can result in crop failure because the roots of corn plants are susceptible to excess water conditions. According to Sirait et al. (2020), corn plants that experience excess water can result in a decrease in production of around 30-50% compared to normal conditions.

The instability of rainfall and temperature conditions in Indonesia can disrupt the quality or quantity of plants. According to the Intergovernmental Panel on Climate Change (2014), a projection of temperature increase in the 21st century will reach 20C if there are no preventive measures. This increase in temperature can have several adverse effects on plants, especially food crops. High temperatures can also result in the availability of water for plant growth being unfulfilled. Increased air temperature caused by climate change can disrupt the photosynthesis process to the respiration process in plants, thereby inhibiting plant productivity (Anripa et al., 2023). Increased temperature in the increasingly high environment can cause transpiration so that plants need more water to evaporate due to adaptation to the high temperature environment. This change can affect the photosynthesis process of plants (Garunna et al., 2014). Disrupted photosynthesis can also disrupt plant productivity.

D. *Climate Projections*

Projection is an estimate of future conditions using existing data. Climate projection is a picture of future climate seen based on changes in greenhouse gas (GHG) composition (Suryadi et al., 2017). A picture of future climate conditions is often referred to as a scenario. Scenarios emphasize understanding the future climate picture and the uncertainty in responding to changes in greenhouse gas emissions and do not predict them (Kusumo and Septiadi, 2016). This climate projection is arranged based on emission scenarios that continue to occur until now. This scenario is assessed based on emission control factors that influence the increase in GHG concentrations in the atmosphere (Surmaini and Faqih, 2016). This can also affect the magnitude of Radiative Forcing (RF, units of W m-2). This RF is the amount of radiation energy that changes when entering and exiting the troposphere layer which is considered to have damaging interference from the radiation energy pattern (Adhayani et al., 2019).

Scenarios based on changes in RF values are the input used to project various changes in climate elements. This information is studied in a global climate model. The Global Circulation Model (GCM) is a global climate model that is widely used in reporting projections of future climate variations (Zhang et al., 2021). The data produced is in the form of a grid region or grid with a resolution of around 2.5 ° or ± 300 km2 that represents the global climate conditions. On a regional scale, a regional climate model (Regional Climate Model) is used to obtain information with higher resolution. The scenario used is called Representative Concentration Pathways (RCP). This RCP can represent the entire estimated range of future RF flows. In this scenario, there are four scenarios that are described from the lowest optimistic to the highest pessimistic. Based on the RCP scenario, there are four different tendencies in the development of greenhouse gas emissions consisting of a strict mitigation scenario (RCP2.6), an intermediate scenario (RCP4.5 and RCP6.0), and a scenario with high greenhouse gas emissions (RCP8.5) (Bienvenido-Huertas et al., 2021). In this study, RCP 4.5 and RCP 8.5 were used. RCP 4.5 represents annual greenhouse gas emissions with a peak around 2040 and a decline in the 21st century, while RCP 8.5 represents a continuous increase in greenhouse gas emissions throughout the 21st century (Yao et al., 2019). The scenario model used can project climate conditions up to 2100.

Research using the Representative Concentration Pathways scenario has been widely conducted, especially in the agricultural sector. One example of research conducted by Fajrianti (2024) which discusses the influence of climate projections on rainfall elements on rice plant productivity until 2045. The scenarios used in this study were RCP 2.6 and RCP 8.5 with 3 different models, namely MOHC-HadGEM2-ES, MPI-M-MPI-ESM-MR and NCC-NorESM1-M. The results of this study show an increase in rice plant productivity in 2045 in the RCP 2.6 scenario and a decrease in rice plant productivity in Malang and Banyuwangi Regencies. In addition, scenario 2.6 shows a relatively stable increase in rainfall and RCP 8.5 shows more extreme rainfall variations.

E. *The Effect of Altitude on Water Availability*

Altitude has an effect on water availability. This effect can be seen from several aspects such as climate, water resources and vegetation. Areas with higher altitudes have high rainfall with low evaporation which is inversely proportional to lowlands (Oyler et al., 2015). This also affects the reduction in the rate of evaporation due to lower temperatures at high altitudes. Altitude can affect the characteristics and ability of the soil to store water. In a study by Rad et al., (2021) showed that corn plants planted in the highlands are more susceptible to water stress than in the lowlands, especially in areas with insufficient rainfall. In addition, low water availability can affect the yield of the plant. In its growth, corn plants on land that does not have irrigation require optimal rainfall of around 85-200 mm/month (Paeru and Dewi, 2017).

III. RESEARCH METHODOLOGY

This research was conducted in December - January 2025 at the East Java Climatology Station. The research was conducted by examining the corn production areas in East Java Province located in Tuban Regency and Malang Regency. The map of Tuban Regency and Malang Regency is presented in Figure 3. Tuban Regency is one of the regencies located in East Java Province. Tuban Regency is located at 111030 '- 112035' East Longitude and 6040' - 7018' South Latitude which is presented in Figure 3a. Tuban Regency is directly adjacent to the Java Sea to the North, Lamongan Regency to the East, Bojonegoro Regency to the South and Central Java Province to the West. Tuban Regency is at an altitude of 5-182 meters above sea level (masl). In 2023, the annual rainfall of Tuban Regency was 907.8 mm with 104 rainy days and the average temperature of Tuban Regency ranged from 27.1°C - 29.7°C (Central Statistics Agency of Tuban Regency, 2024).

Malang Regency is located in the South Central part of East Java Province. Malang Regency is located between 112.060 - 112.070 East Longitude and 7.060-8.020 South Latitude which is presented in Figure 3b. Malang Regency borders Pasuruan and Probolinggo Regencies to the North-East, Lumajang Regency to the East, the Indonesian Ocean to the South, Blitar Regency to the West and Kediri and Mojokerto Regencies to the North West. Malang Regency is located at an altitude of 250-500 meters above sea level (masl) in the central region, 0-650 meters above sea level (masl) in the southern region, 500-3,600 meters above sea level (masl) in the eastern region from north to south and 500-3,300 meters above sea level (masl) in the western region. In 2023, the annual rainfall of Malang Regency is around 1686 mm with 151 rainy days and an average temperature ranging from 22.4°C - 25.76°C (Central Statistics Agency of Malang Regency, 2024).

The tools used in the study include Spreadsheet and R Statistic applications. The materials used in this study are monthly rainfall projection data, minimum temperature, maximum temperature and average temperature. In addition, there is also data on the longitude and latitude of the study area, root depth, depletion fraction, pan evaporation, crop coefficient and correction factor. The climate projection scenario data used is the Representative Concentration Pathways (RCP) 4.5 and 8.5 REG CM 4 and CSIRO MK 3.6 models. This study uses a descriptive analysis method which is a statistical method used to analyze data by describing or describing the data collected to provide an overview of the problems that occur. The descriptive method is a method used to analyze by describing problems that have occurred or that have occurred. This method is described in the form of tables, graphs, diagrams, or measures of data centralization and distribution. In preparing the research, it is also necessary to conduct a literature study to analyze the problems that occur and also previous research on the problem. After the problem of interest to the researcher is determined, information from previous studies is collected. Furthermore, data collection in the form of climate data from 1991-2020 and projection data for 2021-2099. In addition, there is also other data used to calculate irrigation needs and potential harvest yields.

The technique for determining the location of the study used the purposive sampling method. According to Sugiono (2015), purposive sampling is a sampling technique based on certain considerations according to the required criteria. The criteria determined are based on the area of corn production centers and represent different altitudes in the regions in East Java Province. The areas selected in this study were Tuban Regency which represents the largest production center in East Java Province and Tuban Regency which represents the lowlands and Malang Regency which represents the Middle Plains. The scope of this area is designed to represent the diversity of climate conditions such as rainfall and temperature in different regions. In addition, in Tuban Regency and Malang Regency, 1 sub-district with the largest production in each region was taken to determine the land point that would be used as the coordinate point in determining the data. The coordinates used in Tuban Regency are 8.316137 ° and 112.398505 °. while the coordinates used in Tuban Regency are 6.890742 ° and 111.888973 °. The data used and collected in this study are historical climate data, projection data and data for calculating the water requirements of corn in Tuban Regency and Malang Regency. The data collected are secondary data consisting of: Historical rainfall and temperature data from 1991-2020 obtained from the Meteorology, Climatology and Geophysics Agency. Climate projection data from the East Java Climatology Station from 2021 to 2080. The climate model data used are REG CM 4 and CSIRO MK 3.6 in the RCP 4.5 and RCP 8.5 scenarios. Field Capacity (KP) data with a value of 462 mm and Permanent Wilting Point (TLP) with a value of 229 mm from the Harmonized World Soil Database (HWSD) website and research by Prasojo et al., (2022). Longitude and latitude data for the study area to extract projection data. Root depth, depletion fraction, and crop coefficient data obtained from FAO 56. Pan evaporation data obtained from the East Java Climatology Station.

The collected data will be processed by making projections from the models obtained for each parameter based on projection data from RCP 4.5 and RCP 8.5. The climate projection model used is described in Table 1. The data processing process is carried out using the R-statistic application with a script quoted from Kurniawan's research, (2024) with the following steps presented in Figure 4. Extraction of projection data for rainfall, maximum temperature, minimum temperature and average temperature. Calculation of evapotranspiration using the Hargreaves-Samani equation method in FAO 56. Validation test on projection data and data with the most accurate validation is selected. Calculation of groundwater availability (KAT) using monthly rainfall, plant evapotranspiration (Etc) and field capacity (KL). Calculation of available groundwater (ATS) using KAT, Field Capacity and Permanent Wilting Point. Calculation of target KAT using KAT and depletion fraction. Calculation of irrigation water requirements and calculation of potential harvest yields. The validation test used in this study is the Mean Absolute Error (MAE). MAE is a method of measuring the level of accuracy in a forecasting model. The MAE value is the average of the absolute error in the forecast results with the real value. In the MAE equation, it can be seen that the calculation of the average error uses the same weight for all data (i = 1). MAE is more intuitive in providing an average error to evaluate the forecasting model from all data. The results of the validation test were carried out on the RCP 4.5 and RCP 8.5 scenarios in the period 1991-2020. The results of the validation test will later be used for climate projection data for the period 2021-2099.

The data analysis used in this study is the calculation of irrigation water requirements based on groundwater availability. The calculation stages carried out include: Field Capacity and Permanent Wilting Point, using soil data from HWSD and certain formulas; Evapotranspiration with the Hargreaves-Samani equation based on temperature data; Plant coefficient based on FAO 56 with Kc values adjusted for each phase; Groundwater Availability (KAT) and target KAT using the Thornwaite-Mather method; and Available Groundwater (ATS) in percent and irrigation water requirements based on the difference in value between the target and actual KAT. All of these stages are used to support the calculation of potential harvest yields based on water conditions during the plant growth period. The corn plant coefficient curve at several growth phases including the early period, development period, middle period and final period is displayed in graphical form and is a reference in calculating water requirements and potential harvest yields. This growth period is directly related to different water requirements, thus providing a detailed picture for decision making in irrigation and harvest projections. This research as a whole aims to provide an overview of future climate projections and their impact on corn plant growth through a measurable and systematic scientific and computational approach.

IV. RESULT & DISCUSSION

The results of the validation test were carried out on the RCP 4.5 and RCP 8.5 scenarios in the period 1991-2020. The results of the validation test will later be used for climate projection data for the period 2021-2099. The validation test was carried out using the Mean Absolute Error (MAE) method with the results presented in Table 5 and Table 7. Validation was carried out on rainfall in Tuban Regency and Malang Regency as well as on maximum temperature, minimum temperature and average temperature. Validation was carried out on two models, namely the CSIRO MK 3.6 model and the REG CM 4 model.

Based on the validation results, the smallest MAE value is used to determine which data is used in the projection. For rainfall data for Tuban Regency and Malang Regency, the data used is the projection data from the CSIRO MK 3.6 model. For maximum temperature, minimum temperature, and average temperature data for Tuban Regency and Malang Regency, data from the REG CM 4 model is used because it has the smallest MAE value compared to other models.

Historical rainfall data for Tuban Regency and Malang Regency are presented in Figure 6 and Figure 7. The figures show the historical trend of rainfall from 1991 to 2020. Furthermore, rainfall projections based on the RCP 4.5 and RCP 8.5 scenarios are shown in Figure 8 to Figure 15 which show projections for the periods 2021-2050 and 2051-2080 for each district.

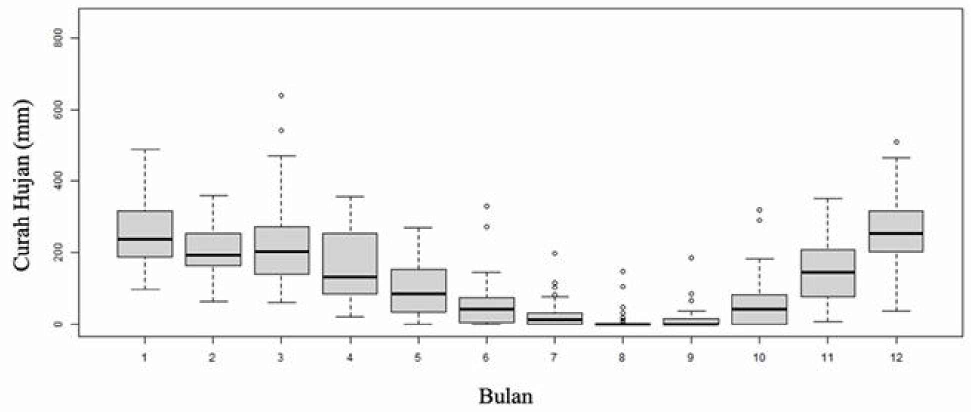

Fig1 Historical Rainfall Data for Tuban Regency

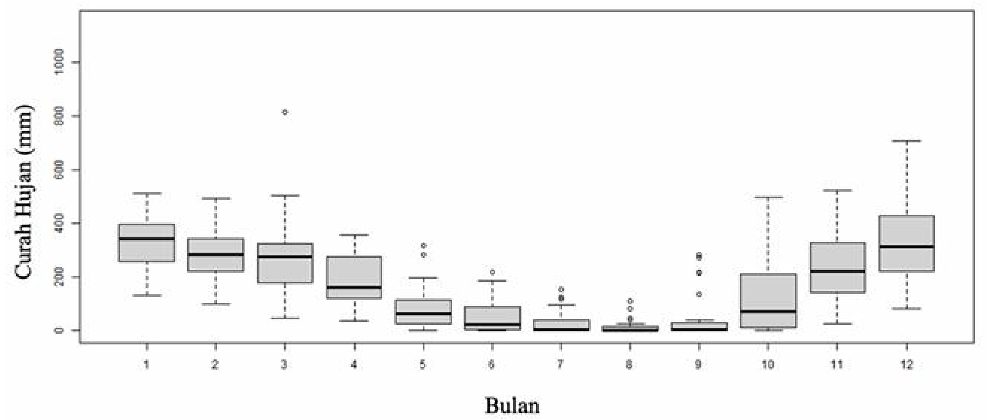

Fig.2 Historical Rainfall Data in Malang Regency

The results of rainfall projections based on RCP 4.5 and 8.5 scenarios in Tuban Regency and Malang Regency show an increase and fluctuation in rainfall. Figures 8 to 11 show rainfall in Tuban Regency and Malang Regency based on RCP 4.5. Figures 12 to 15 show rainfall based on RCP 8.5. RCP 8.5 shows a higher increase in rainfall.

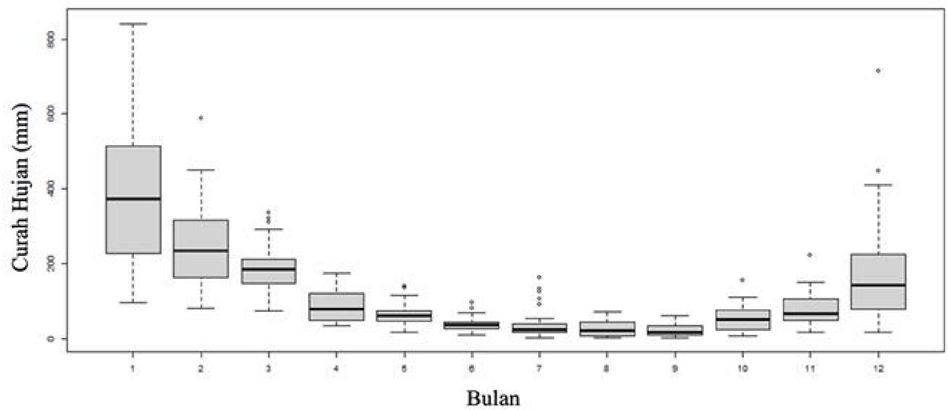

Fig.3 Results of RCP 4.5 Rainfall Projection for 2021-2050 in Tuban Regency

Based on the results of the RCP 4.5 rainfall projection in Tuban Regency in 2021-2050, there has been an increase with a stable trend. The highest rainfall occurs in January and February. The lowest rainfall occurs in August and September. January has an average rainfall of 303 mm and February has a rainfall of 291 mm. In August, rainfall is only 19 mm and in September it is 25 mm. This increase in rainfall is influenced by climate projections which show a gradual increase in rainfall intensity. However, there are dry months that still have low rainfall so good water management planning is needed.

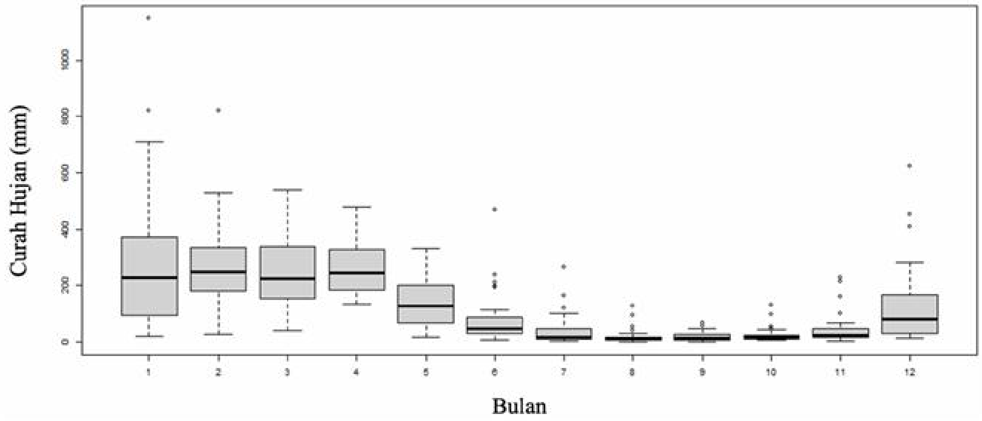

Fig.4 Results of Rainfall Projection RCP 8.5 2021-2050 in Malang Regency

Based on the results of the RCP 8.5 scenario rainfall projection in Malang Regency in 2021-2050, it shows a significant increase in rainfall compared to the historical period. The highest rainfall occurs in January with an average of 403 mm and February with 395 mm. The lowest rainfall occurs in August with 31 mm and September with 45 mm. This increase in rainfall shows a higher wet trend compared to the RCP 4.5 scenario. Although rainfall increases, the dry season still occurs and the dry months still show low rainfall. Therefore, adaptation strategies are still needed to deal with the drought period.

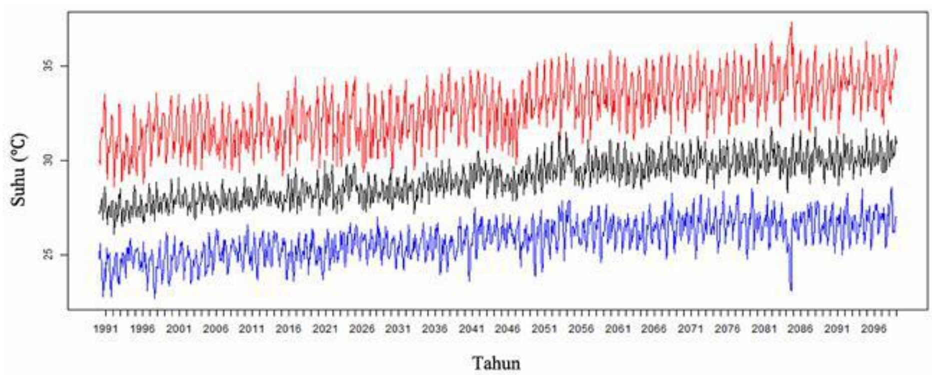

Fig.5 Observation Data and Projection Results of RCP 4.5 Temperature for 2021-2080 in Tuban Regency

Based on the results of temperature projections in the RCP 4.5 scenario for 2021-2099 in Tuban Regency, there has been an increase from year to year. The average maximum temperature is 33.1°C, the minimum temperature is 24.1°C and the average temperature is 28.3°C. This increase in temperature can have an impact on the increasing water needs of corn plants. High temperatures will cause high evaporation and plant evapotranspiration will also increase. This causes the need for irrigation of corn plants to be higher than before.

Evapotranspiration is calculated using the Hargreaves-Samani method. The results of the evapotranspiration calculation are used as the basis for calculating irrigation needs. High evapotranspiration values will affect plant water needs, especially in dry months. Evapotranspiration is also affected by maximum and minimum temperatures which show fluctuations in the projection scenario.

Irrigation water needs are calculated using the same and different assumptions of Kc (crop coefficient) values. The results of the calculation of irrigation needs for Tuban Regency with the same Kc assumption in the RCP 4.5 scenario are shown in Figure 6. Irrigation needs tend to increase in August and September.

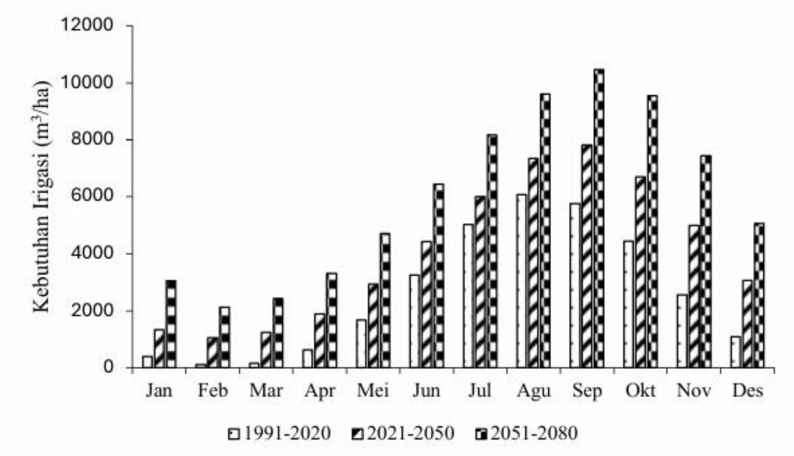

Fig.6 Irrigation Needs Assumption of Same Kc in Tuban Regency RCP 4.5

Based on the results of temperature projections in the RCP 4.5 scenario for 2021-2099 in Tuban Regency, there has been an increase from year to year. The average maximum temperature is 33.1°C, the minimum temperature is 24.1°C and the average temperature is 28.3°C. This increase in temperature can have an impact on the increasing water needs of corn plants. High temperatures will cause high evaporation and plant evapotranspiration will also increase. This causes the need for irrigation of corn plants to be higher than before.

In the RCP 8.5 scenario, the irrigation needs of Tuban Regency increased higher compared to RCP 4.5. This is shown by the illustration showing the irrigation needs with the same and different Kc assumptions. The difference in irrigation water needs is influenced by the projection of increasing temperatures and uneven rainfall. Another illustration shows the irrigation needs of Malang Regency with the same and different Kc assumptions in the RCP 4.5 scenario, as well as in the RCP 8.5 scenario. Malang Regency tends to need lower irrigation water compared to Tuban Regency. The potential yield is calculated based on the availability of groundwater and the water needs of plants during the growing period. Groundwater depletion can have an impact on the yield. Ilustrate show the potential yield of Tuban Regency assuming the same and different Kc values in RCP 4.5.

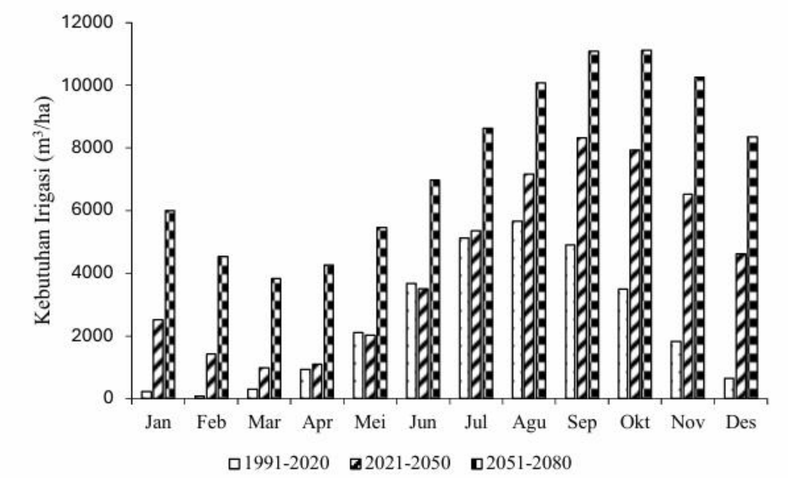

Fig.7 Irrigation Needs Assumption of Same Kc in Malang Regency RCP 8.5

Based on Figure 7, the irrigation water requirement Kc is the same in Malang Regency, RCP 8.5 scenario. The highest irrigation requirement occurs in August at 112 mm and September at 95 mm. Irrigation requirements in November to March show a figure of 0 because rainfall is high enough to meet plant water requirements. Irrigation requirements increase in the dry season, especially in dry months with low rainfall. Malang Regency has lower water requirements compared to Tuban Regency due to higher rainfall and lower temperatures.

Figure 8 shows the potential harvest of Tuban Regency assuming the same and different Kc values in the RCP 8.5 scenario. The potential harvest decreased especially in months with low water availability. Tuban Regency showed a more drastic decrease in harvest. The potential harvest of Malang Regency in the RCP 4.5 scenario is shown in Figure 32 and Figure 33. Meanwhile, for RCP 8.5 it is shown in Figure 34 and Figure 35. Malang Regency experienced a decrease in harvest that was not too significant because rainfall was higher and temperatures did not increase as sharply as Tuban Regency.

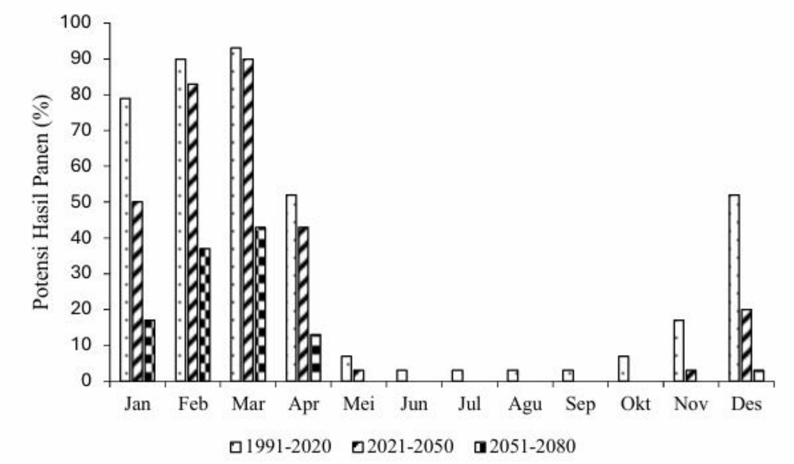

Fig.8 Potential Harvest Yield Assuming Same Kc Value in Tuban Regency RCP 8.5

Based on Figure 8, the potential yield of Kc is the same in Tuban Regency, RCP 8.5 scenario. The highest potential yield occurs in January at 6.81 tons/ha and February at 6.65 tons/ha. The lowest potential yield occurs in September at 4.37 tons/ha. The decrease in potential yield is caused by the high need for irrigation water which is not balanced by the availability of groundwater, so that the plants experience a water deficit. Water deficit in corn plants will disrupt growth, especially in the generative phase and result in a decrease in yield.

Based on the projection of rainfall and temperature in the two study areas, namely Tuban and Malang Regencies, it shows fluctuations from 1991 to 2080. Historical data shows the same seasonal rainfall pattern between the two regions seen at the peak of the rainy season which is in December to March and the dry season in May - September. In the period 2021-2050 using RCP 4.5, rainfall is projected with a relatively high rainfall intensity in the rainy season, namely in January - March reaching 400 mm and the dry season in June-October. While in scenario 8.5, rainfall shows higher variations compared to RCP 4.5 in the rainy season and a fairly high decrease in the dry season in July - October. In the period 2051-2080 which is projected using RCP 4.5, it shows a fairly high rainfall intensity with a rainy season in January to March with a lower dry season compared to the previous year period, namely in July to October. Meanwhile, in projection 8.5, rainfall increases quite sharply and the dry season shows almost zero rainfall. Tuban and Malang Regencies have the same rainfall distribution pattern, but Malang Regency has a higher rainfall intensity (Figure 14).

The rainfall distribution pattern in Tuban and Malang Regencies has a difference in rainfall intensity which is slightly higher in Malang Regency. This is because Malang Regency has a higher elevation compared to Tuban Regency which is at a lower altitude. Elevation or height of a place has a significant influence on the climate factors of rainfall and temperature, where rainfall will increase on higher surfaces (Lesik et al., 2020). In addition, altitude can also affect air temperature which causes a decrease in temperature. Malang Regency has a lower temperature with the highest temperature at 35°C while in Tuban Regency the highest projected temperature reaches 38°C in the RCP 4.5 scenario. In the RCP 8.5 scenario, the highest temperature in both regions ranges from 35-40°C. This is in accordance with the opinion of Zhang et al. (2019) that temperature projections will result in a greater increase in maximum and minimum temperatures using the RCP 8.5 scenario compared to RCP 4.5.

Based on the projection results using RCP 4.5 and 8.5, it can be seen that the RCP 8.5 scenario has a higher value when compared to the RCP 4.5 scenario. According to Khoirunisa (2022), the prediction results for 2021-2080 show that the 4.5 scenario as a pessimistic scenario with radiative forcing (RF) of 4.5 w/m² in both aspects is more stable, while the 8.5 scenario with RF around 8.5 w/m² experiences an unstable decrease and increase. This Radiative Forcing is a parameter for determining climate change. The RF value is directly proportional to the energy entering the earth. This is inversely proportional to the change in the level of CO_2 concentration, which is getting smaller, meaning that more energy will enter (Prasetiawan, 2015). Increases in maximum and minimum temperatures exceeding 3.4 and 3.8°C can result in soil degradation and water shortages, which can significantly reduce crop yields.

According to IPCC calculations, the global average temperature will increase by around 2°C by 2100 and 4.2°C by 2400 (Malhi et al., 2021). Corn plants can generally grow optimally at temperatures of 28 - 32°C. This increase in temperature and decreased water availability can reduce the duration of the growing season in corn plants by up to 16 days (Ahmad et al., 2020). This can disrupt the reproductive period in corn and affect the yield of corn seeds. According to Shao et al. (2021), corn plants exposed to temperatures of 35°C and above, especially during the reproductive period, can affect the success of reproduction and seed formation. High temperatures can damage the embryo so that germination will be delayed. High temperatures can also cause faster plant phenological phase transitions, increased leaf transpiration rates and reduced photosynthesis rates (Chen et al., 2020). As a result, corn plant productivity will decrease due to increasing temperatures, while rainfall becomes uneven.

V. CONCLUSION

Based on the projection of RCP 4.5 and 8.5 scenarios, decreasing rainfall and increasing temperature in Tuban and Malang districts are correlated with increasing irrigation water needs, especially in August and September, while potential yields are expected to decrease with Tuban district being more vulnerable due to lower rainfall. For further research, it is recommended to use direct calculation data through field testing to improve accuracy, as well as to explore adaptation strategies and impacts on farmers in dealing with decreasing corn yields..

ACKNOWLEDGEMENTS

An acknowledgement section may be presented after the conclusion, if desired.

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