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Application of the Arima Method to Prediction Maximum Rainfall at Central Java Climatological Station

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Abstract: The existence of extreme weather that is difficult to predict results in frequent hydrometeorological disasters. ARIMA is a prediction method that can capture trend patterns, seasonal cycles, and random fluctuations that are often found in patterned data. Although many samples of rain data collection points are needed to produce denser data, one point can be considered to represent an area that is not too large, such as Semarang City. This method is quite accurate for short-term forecasts, with the results of monthly maximum rainfall forecasts in 2023 showing varying MAPE values. For the 12-month forecast, prediction results range from fair to very accurate. The 7-month forecast also shows decent to very accurate results. However, the 5-month forecast shows less accurate results. This shows that ARIMA can be a useful method in forecasting monthly maximum rainfall, especially during the dry season. The application of ARIMA in Semarang City can help in planning hydrometeorological disaster mitigation, considering that the Semarang City area often experiences extreme weather that is difficult to predict. Thus, the use of ARIMA can provide significant benefits in preparing for and reducing the impact of hydrometeorological disasters in the region. In addition, with more accurate forecasts, the government and society can take preventative steps earlier, such as better water management, creating an adequate drainage system, and increasing public awareness of the threat of disasters. Therefore, this research emphasizes the importance of using reliable prediction methods such as ARIMA to improve preparedness in dealing with hydrometeorological disasters.

Keywords: ARIMA; MAPE; sample; rainfall; prediction; maximum.

INTRODUCTION

Predicting maximum rainfall is quite difficult because the variability of rainfall between one region and another varies depending on topographic and geographic conditions. Time series analysis is used to analyze data in a way that minimizes time variance. The analysis above can be used to forecast climate data over several time periods, which will help forecasters anticipate the amount of rainfall that will occur in the future period (Rachmawati & Anifah, 2019). Differential time analysis is a type of analysis designed based on time intervals. Time series analysis is useful in many fields, especially climatology. One of the main aspects of climatology is rainfall which can provide benefits to humans. Where rainfall has different variations making it difficult to predict, the best method must be used to make rainfall predictions (Safitri et al., 2021) the forecasting method consists of two methods, namely quantitative and qualitative methods. Quantitative methods are an approach that is similar to time series methods or also called time series. Quantitative methods are classified into two categories: regression and time series methods.

The short availability of historical data can limit the ability of prediction models to study rainfall patterns and make accurate predictions, besides that inconsistent data quality, such as missing values or outliers, can reduce the accuracy of maximum rainfall predictions. Rainfall is influenced by various factors, such as global, regional and local atmospheric conditions, which are complex and interrelated, so this makes predictions difficult and requires models that are sensitive to changes in these patterns. Rainfall prediction models are not perfect and have inherent errors which can cause inaccuracies in predictions, so selecting the right forecasting model is a must.

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Develop a forecast model that is able to provide accurate calculations and can take into account factors that influence rainfall. Improve the quality and quantity of data available for forecasting. Using a model that is able to capture patterns and trends in rainfall data, it can produce more accurate forecasts compared to traditional methods. The model can be modified to account for various factors that influence rainfall, such as seasonality, El Niño, and La Niña. The model is easy to use and implemented in a variety of statistical software. Producing accurate maximum rainfall forecasts can help farmers determine planting and harvest times, thereby increasing crop yields, assisting in the management of water resources, such as reservoirs and dams, so as to prevent floods and droughts.

Several researchers use the ARIMA method for analysis and prediction, including (Misshuari et al., 2023) using the ARIMA method to predict rainfall in the Asahan area of North Sumatra, by understanding and making evaluations of rain patterns that may occur, hopefully this research can provide benefits to people who need climate information to anticipate hydrological disasters caused by extreme rainfall . Apart from that, there are also researchers from Makassar who use ARIMA to predict seasonal rainfall (Nensi et al., 2023). Rain predictions with ARIMA can also be used to improve agriculture, mitigate flood disasters, or improve other fields(Nandarie et al., 2023) While (Nanda Tria Lestari & Witanti, 2023) also conducting research using ARIMA with the title Prediction of dengue cases based on weather factors using multivariate ARIMA analysis. In this research, weather factors, namely humidity and rainfall, were identified through analysis results. The results of evaluating prediction accuracy using the applied model are shown by a Mean Absolute Percentage Error (MAPE) of around 18,12.

LITERATURE REVIEW

According to (Ariyanti & Tristyanti Yusnitasari, 2023) The need for oil is increasing and affecting economies throughout the world. As world crude oil prices rise, domestic oil prices also rise. To anticipate undesirable events, world crude oil price forecasts are needed so that the government can anticipate the effects of these increases. To make forecasts for world crude oil prices, the ARIMA method was used using daily data on world crude oil prices for 2020 - 2023 and obtained an RMSE result of 1,905. This result shows that ARIMA is suitable for forecasting world crude oil prices.

ARIMA can also be used to calculate rainfall predictions in a place using data series from BMKG. Rainfall forecasts are very important so that people can make plans in the agricultural or development sectors. Rainfall variability like today really requires a method or algorithm that is suitable. for predictions. One method that is often used is ARIMA. Usually the data used is data based on time series. By using ARIMA in making rainfall forecasts, we get an MSE value of 17.49. With a large enough MSE value, it is possible to use other, better methods (Susilokarti et al., 2015).

In relation to weather or rainfall as a limiting factor for rice plants, rice plants are very dependent on rainfall. This can affect the price of rice on the market. To anticipate the prices of basic necessities, including rice, it is necessary to have price forecasts for basic commodities, one of which is the rice price forecast. For this reason, the government uses a method that has already been created, namely using the ARIMA method to predict rice prices with an RMSE value of 313.379941(Mardianto et al., 2020).

In order for rice or secondary crops to be successful, it is necessary to estimate the planting period using rainfall data so that rice or secondary crops planting period forecasts can be made. Planting periods or planting calendars are very necessary for farmers to anticipate crop failure, so that farmers can plant according to the needs of available water. To make predictions for the planting period or start of planting, you can use ARIMA with an RMSE value of 2.88 and a MAP value of 0.597 (Recksy et al., 2023).

Apart from forecasting planting periods, ARIMA can also be used to make temperature forecasts. An example of a temperature forecast that has been carried out is the prediction of air temperature on electrical power usage in East Kalimantan. With good forecast results with a MAPE value of less than 10% (R. Susanti & Adji, 2020).

The increase in temperature and high rainfall also triggers an increase in cases of dengue fever, because mosquitoes can reproduce quickly according to environmental conditions. To anticipate large outbreaks that can cause death, we need a way to predict when mosquitoes will become an outbreak. With the ARIMA method, we can predict dengue cases based on weather conditions. In predicting dengue cases using ARIMA, an MAE value of 18.12 was obtained (Nanda Tria Lestari & Witanti, 2023).

Apart from temperature and rain, a weather element that can be utilized by humans is wind, where wind can be used as a wind power plant, usually abbreviated as PLTB (Wind Power Plant). So strong winds can be used to move turbines so they can produce electrical power. To find out how strong the wind can move the turbine, we need a method that can be used to predict electrical power. For this reason, you can use the ARIMA method in the calculations where the data can be divided into test data and training data with a ratio of 70:30, with an RMSE value for the test data of 2,569 and an RMSE for the training data of 2,266 (Asy'ari et al., 2023).

Other researchers (Pangaribuan et al., 2023) used the ARIMA method in evaluating the success of sales predictions, which emphasizes the accuracy and reliability of the model in predicting property sales trends. In this case it highlights the positive impact of accurate predictions on business strategy, inventory management, financial risk reduction, and strategic decision making in dynamic real estate markets. Sales Forecasting, with the ARIMA

*name of corresponding author

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method helps in accurate sales forecasting, enabling companies to plan and control their production according to consumer needs. This helps in optimizing resources and avoiding overproduction, leading to cost savings. By providing reliable sales predictions, the ARIMA model supports informed decision-making processes in the property business. This allows companies to make strategic choices based on realistic sales projections. The ARIMA model used in this research shows a high level of accuracy in predicting home business property sales. The selected ARIMA model (9,1,10) provides good forecasting results with low AIC and BIC values, indicating its effectiveness in producing precise forecasts. The accuracy of ARIMA models is evaluated using metrics such as RMSE, MSE, and MAPE. This metric helps in assessing the performance and reliability of the model in predicting future sales trends. In this study, the ARIMA model demonstrated a low RMSE of 0.281409, MSE of 0.079191, and MAPE of 3.4%, demonstrating its ability to provide reliable sales forecasts.

Another researcher, namely (Zahrunnisa et al., 2021) compared two forecasting methods, namely Exponential Smoothing (DES) and ARIMA, in predicting the poverty line in Central Java. Poverty line data in Central Java Province sourced from the official news website of the Central Statistics Agency (BPS) of Central Java Province. The poverty line is an important indicator for measuring the level of community welfare. These two methods were chosen because they have their respective advantages in predicting time series data, especially financial data. DES is good for data with trends, while ARIMA is suitable for short-term predictions and data that is difficult to explain in economic theory. This study uses the MAPE (Mean Absolute Percentage Error) value as a benchmark to determine which method is the most accurate in predicting the poverty line in Central Java. The MAPE value of the DES method: 2.99%, while the ARIMA method is 6.61%.

Several researchers in using the Arima method obtained maximum results, namely the Box-Jenkins Method, a statistical method used for forecasting time series data. This method uses past data as the dependent variable. The data used in this study is data on the amount of rice production in Maros Regency taken from 2001 to 2018 which was taken from the Central Statistics Agency of Maros Regency and the Food Security, Food Crops, and Horticulture Service of South Sulawesi Province. The results obtained show that the ARIMA (0,2,1) model is a suitable model for predicting the amount of rice production in the Maros Regency. The estimated results show that the amount of rice production in Maros Regency has increased every year with an average increase of 3807.1 tons (Nurman et al., 2022).

METHOD

ARIMA METHOD

The method used in this research is the ARIMA method. This research uses maximum rainfall data of 30 years. The data used in this research is monthly maximum rainfall data for 30 years (1993–2022) from the Central Java Climate Observatory. In this study using the Arima method because the Arima method is easy to find in various software for free and is already in the HyBMG application (an application for predicting basic and monthly rainfall which is a product of the BMKG Research and Development Center), using the Arima method can be used for long-term and medium-term predictions. Arima is also very flexible in making forecasts using data patterns including trends and seasonality so that the data becomes stationary.

Another study comparing Brown's Double Exponential Smoothing and ARIMA methods yielded the most accurate prediction period for the effectiveness of each method in the short term at around three months (Saragih & Sembiring, 2022). Approach The goal of ARIMA is to identify a reliable model that can accurately represent the start and end times of a time series data. ARIMA itself comes from a combination of three models used (Misshuari et al., 2023), namely:

Autoregressive (AR): This model predicts the age of a variable based on its previous value. The AR expression is:

$$Y_t = \phi_1 Y_{t-1} + \phi_1 Y_{t-2} + \cdots + \phi_p Y_{t-p} + a_t \quad (1)$$

In this case, ϕ is an autoregressive parameter, and Yt is the time series value t, and p is an autoregressive function.

Integrated (I): This step is carried out to stabilize the data, namely data whose average value does not change with time. Below are the components of formula I:

$$(1 - B)^d Y_t \quad (2)$$

In this case, B is the backshift operator (time derivative), where Yt is the value of the time series at time t, and d is the order of the derivative.

Moving Average (MA): This model takes into account the average error of past predictions to improve future predictions. The MA model helps identify patterns and variations that cannot be explained by the autoregressive component, the following components of the equation are:

*name of corresponding author

$$\theta_1\varepsilon_{t-1} + \theta_2\varepsilon_{t-2} + \cdots + \theta_q\varepsilon_{t-q} \quad (3)$$

Where θ is the running average parameter, εt is the residual or error at time t, and q is the moving average formula. Combining these four components allows the ARIMA model to be able to predict future values based on the values of previous patterns within a certain time period. Combining these four components gives a general solution to the ARIMA (p, d, q) model:

$$(1 - \phi_1 B - \phi_2 B^2 - \cdots - \phi_p B^p (1 - B)^d Y_t = \left(1 + \theta_1 B + \theta_1 B^2 + \cdots + \theta_q B^q\right)\varepsilon_t \quad (4)$$

Based on the formula above:

ϕ1, ϕ2,…,ϕp are autoregressive parameters.
B is the backshift operator (time derivative).
d is the order of differentiation (order derivative).
Yt is the time series value at time t
θ1, θ2,…,θq are moving average criteria..
εt is the error (residual) at time t.

Formally, the ARIMA model is displayed by (p, d, q), here: p (AR order) indicates the autoregressive sequence, namely the number of previous periods used in the model. d (order I): shows the order of differentiation/derivation, namely the number of times differentiation/derivation needed to make the data stationary, while q (order/order MA): shows the order of the running average, namely the number of moving average values used in the model.
To calculate the accuracy of ARIMA forecast results, it is done by calculating the Mean Absolute Percentage Error (MAPE) (Nabillah & Rangadara, 2020). MAPE is a metric commonly used in forecasting analysis and prediction model evaluation to measure how accurate the model is in predicting future values (Recksy et al., 2023). MAPE calculates the average absolute percentage error between predicted and observed values. A model is considered good if the residuals between the predictive model results and past observation data are small enough, randomly distributed, and independent of each other. MAPE provides an explanation of how big the prediction error is compared to the actual value or observed value from the calculations carried out. The MAPE value (Mulyani et al., 2022). can be calculated with the following equation:

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{X_t - F_t}{X_t}\right| x100\% \quad (5)$$

Based on the formula above

Xt = Real data/observations in the t-th period
Ft = Forecast data in the t-th period
n = Amount of data

Interpreting MAPE values:
MAPE < 10% : Predictions are very accurate.
MAPE 10% - 20% : Good prediction.
MAPE 20% - 50% : Decent prediction.
MAPE > 50% : Inaccurate predictions.

ARIMA Method Design
At this stage, we will discuss the design of processing maximum monthly rainfall data for 30 years (1993 – 2022) using the ARIMA method. This activity starts by inputting maximum monthly rainfall data for 30 years, then the data is processed or processed using TXT or Notepad data format.
Next, select the ARIMA model in the HyBMG application and run it. The Arima model was developed to overcome the inadequacies of the ARMA (Autoregressive and Moving Average) model (R. Susanti & Adji, 2020). The statistical model used is based on the HyBMG model, while the dynamic model comes from the ECMWF model. HyBMG is a statistical prediction model application developed by BMKG Puslitbang (Research and Development Center) which can be used to make individual climate predictions on a daily or weekly basis. The statistical prediction module uses univariate methods ARIMA, ANFIS, Wavelet ANFIS, and Wavelet ARIMA available in the HyBMG application (Ruslana et al., 2021).

*name of corresponding author

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The next step is to evaluate the prediction results of the ARIMA execution model. Calculations are carried out using MAPE to determine the level of accuracy of maximum rainfall predictions.

The MAPE test shows how much the prediction results deviate from accuracy. MAPE (Mean Absolute Percentage Error) testing reveals significant differences between dynamic and static testing approaches. The two different dynamic approaches introduce several important drawbacks to MAPE testing compared to static test loads (Novandro et al., 2023).

To make this design easier, it was implemented using a Flowchart (Ma et al., 2018). The following is a flowchart of the maximum rainfall data processing process:

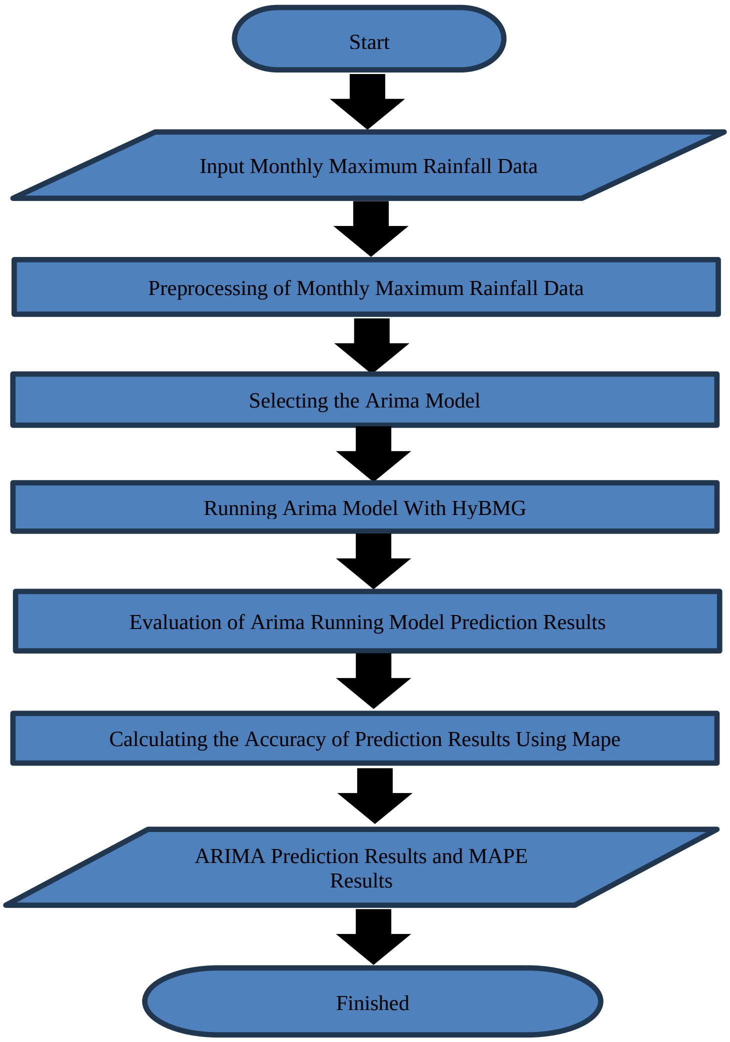

Fig. 1 Flowchart of ARIMA and processing algorithms MAPE

RESULT

This maximum rainfall forecast uses maximum monthly rainfall data from the Central Java Climatology Station for 30 years, from January 1993 - December 2022. This data is processed and used to make maximum rainfall forecasts for 2023 in Semarang City using the ARIMA method. From the forecast results using ARIMA, the following results were obtained (L. Susanti et al., 2020):

Table 1. Maximum Rainfall Forecast Results and MAPE calculations.

Information	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Des
Real Data 2023	137.6	62.2	47.4	40	28.7	33.6	61.2	28.7	2.8	11.4	38	97.8
Max. Rainfall Forecast 2023	71	84.5	43.1	42.6	57.3	36.4	26.1	24.9	31.4	49.7	67.9	75.1

*name of corresponding author

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MAPE Value	48	-36	9	-7	-100	-8	57	13	-1021	-336	-79	23

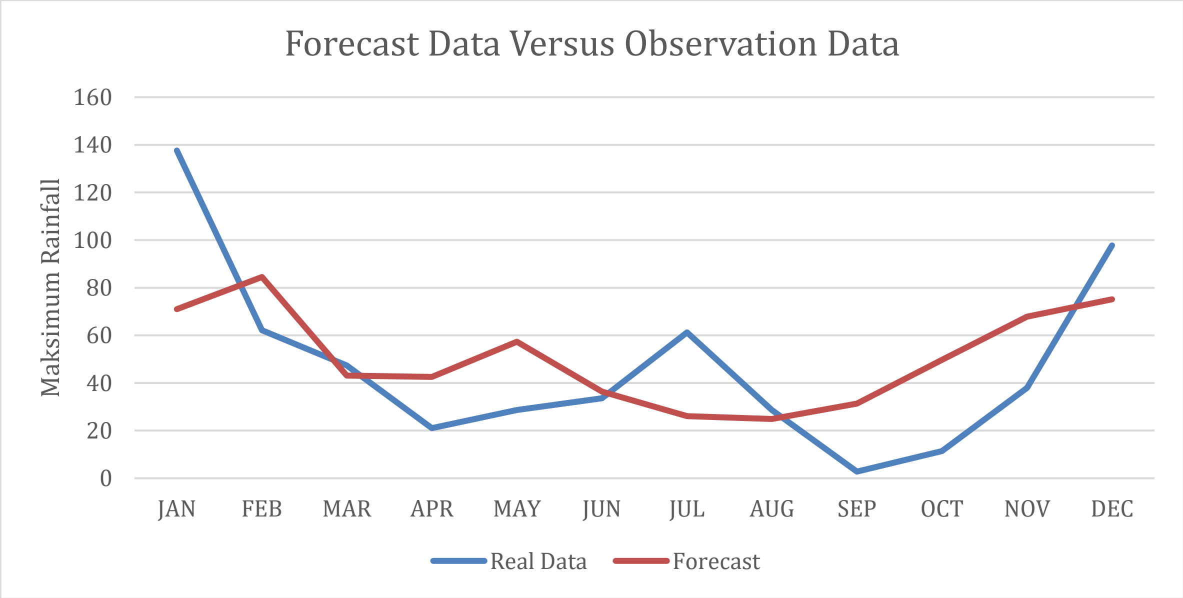

Fig 2. Precipitation Versus Precipitation Forecast Rain Observation

From the fig 2, can be seen that the pattern of maximum rainfall forecasts and observed rainfall (Nandarie et al., 2023). The prediction results for one year, namely January to December 2023, from the forecast results for January of 71 mm, February of 84.5 mm, March of 43.1 mm, April of 42.6 mm, May of 57.3 mm, June of 36.4 mm, July of 61.2 mm, August of 24.9 mm, September of 31.4 mm, October of 31.4 mm, November of 67.9 mm and December of 75.1 mm, It can be seen that the maximum rainfall forecast which matches the observed rainfall is in March, April, June, August in 2023. The maximum rainfall data is the highest rainfall data for one month (the highest rainfall data in one day in that month in millimeters/day). Referring to the BMKG daily rainfall intensity criteria, namely Light Rain is 5 - 20 mm/day, Moderate Rain is 20-50/day, Heavy Rain is 50 - 100 mm/day, Very Heavy Rain is 100-150 mm/day, Extreme Rain is > 150 mm/day, so that the intensity of the maximum rainfall forecast results can be known.

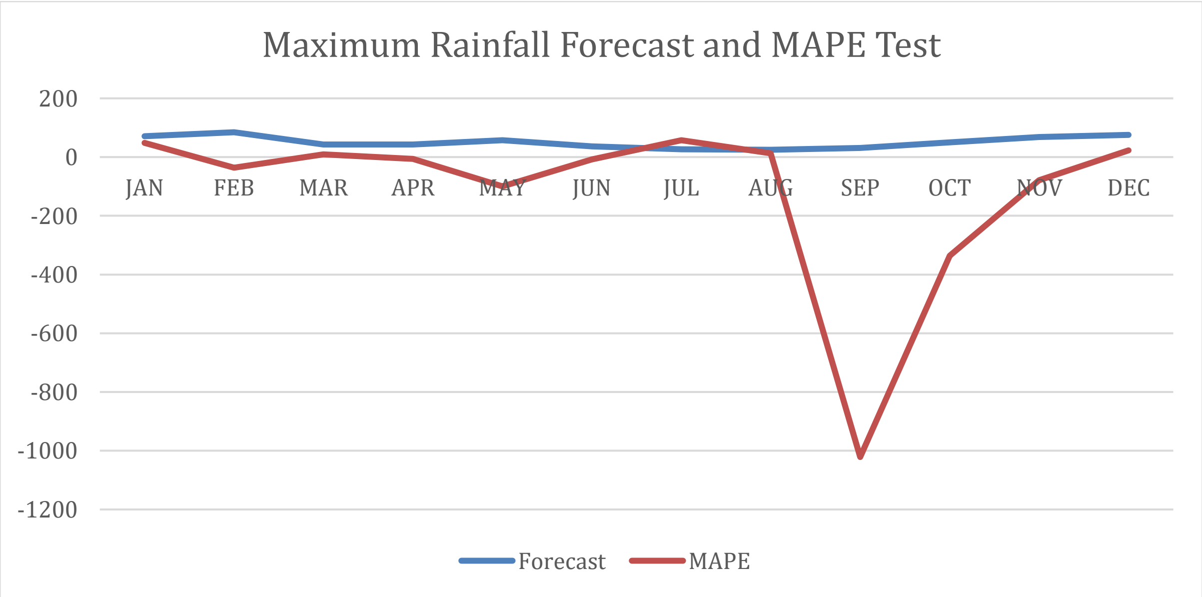

Fig 3. Maximum Rainfall Forecast and MAPE Test

*name of corresponding author

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MAPE value for January was 48%, February was -36%, March was 9%, April was -7%, May was -100%, June was -8%, July was 57%, August was 13%, September was -1021%, October was -336%, November was -79%, and December was 23%. From the maximum rainfall forecast and MAPE test graph (fig 3), the highest MAPE test value is the forecast rainfall for September, and the maximum rainfall forecast for September is 31.4 mm, while the maximum observed rainfall is 2.8 mm. Based on the MAPE test value, the interpretation of the predicted MAPE value is very accurate with a MAPE value <10% in three months, namely March, April and June. For good predictions with a value of 10 - 20% it occurs in August. A feasible prediction with a MAPE value of 20 - 50% occurs in January, February and December. Meanwhile, inaccurate predictions with MAPE values >50% are May, September, October and November. High MAPE values > 50% this occurs in May, October and November occurs because data that has outliers (extreme rainfall values that are far from most data) can cause prediction errors and increase the MAPE value quite significantly. September produces a very large value because the actual value is close to zero, which is 2.8 mm/day, a small difference between the prediction and the actual value can produce a large MAPE value because in the MAPE calculation, the difference is divided by the actual value.

DISCUSSIONS

Further research needs to be conducted to find the best method for making maximum rainfall forecasts other than using the Arima method. For this research, it is possible not only to use one sample for Semarang City, but more than one sample. Making predictions of maximum rainfall using the Arima method is expected to be able to determine the maximum rainfall intensity on a daily scale in each month, and can take mitigation measures for hydrometeorological disasters such as floods, landslides, droughts and for related agencies it can also be used to calculate the amount of water that can be stored in reservoirs or ponds so that it can be used during the dry season.

CONCLUSION

The maximum rainfall forecast that best matches Observation rainfall is in March, April, June, August, December. The highest MAPE Test value occurs during the maximum rainfall forecast in September. Based on the MAPE test values, the interpretation of the predicted MAPE values is very accurate and feasible, namely January, February, March, April, June, August and December. Meanwhile, inaccurate predictions with MAPE values >50% are May, September, October and November.

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