IPC

Indonesian Physics Communication

Department of Physics, Universitas Riau, Pekanbaru, Indonesia
p-ISSN 1412-2960 | e-ISSN 2579-521X

Vol. 21 | No. 3
November 2024

Web: https://kfi.ejournal.unri.ac.id
E-mail: kfi@ejournal.unri.ac.id

Prediction of Pekanbaru City rainfall using dynamic models

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ABSTRACT

The need for predictions is very necessary in various sectors of life, one of which is rainfall predictions. The threshold value for PM_{10} particles that is allowed to be in ambient air is, 150 µgram/m^3/day). The aim of this research is to create a dynamic model predicting Pekanbaru City's rainfall for the next 3 years. Rainfall prediction in this research was carried out using the dynamic system modeling method with Powersim software. The data used is BMKG data for the Pekanbaru City for 5 years (2015 – 2019) using 4 parameters, namely rainfall, air humidity, wind speed and temperature. Prediction results show that air humidity in Pekanbaru City has the same pattern as BMKG, namely the highest month is December and the lowest is August. Wind speed prediction results are highest in July and lowest in May. The highest temperature in Pekanbaru City is in April and the lowest is in January. Rainfall for 2020 – 2021 is predicted to experience light rain on average, because it has the same data pattern on the variables that influence it. So it can be interpreted that the validation results for air humidity, wind speed and temperature in Pekanbaru City show that they are valid because they do not exceed the limit value of $\leq 5\%$.

Keywords: Dynamic model; Pekanbaru City; prediction; rainfall

Received 26-09-2023 | Revised 19-10-2023 | Accepted 06-11-2024 | Published 30-11-2024

INTRODUCTION

Particulates (PM_{10}) are airborne particles that are smaller than 10 microns (micrometers). The threshold value of PM_{10} particles allowed in ambient air is 150 µgram/m^3/day [1]. Specifically in Pekanbaru City in 2019 in July the PM_{10} value was still below the NAB, which was around 48.89 µgram/m^3/day. In August the PM_{10} value was 80.44 µgram/m^3 and the September PM_{10} value exceeded the quality standard threshold value with a very unhealthy category, namely with a value of 245.94 µgram/m^3 [2].

The increase in PM_{10} values is caused by forest and land fires in the area around Pekanbaru City, as well as the dry season which also worsens air quality due to the absence of rain to reduce the deposition of air pollutants [2-4]. Rainfall can remove pollutants in the atmosphere, pollutants will be directly washed by rainwater and then deposited on the surface [5-9]. Rainfall data for the last 5 years obtained from BMKG shows that September was a dry month. The amount of rainfall in September amounted to 28 mm, while the previous 2 months, July and August experienced moderate rainfall months with rainfall amounts of 119.2 and 148.7. There has been a lot of research on rainfall, one of the studies that predict rainfall was conducted by Oktaviani and Afdal (2013) in Padang City [10]. This research is to recognize rainfall patterns using traingdx. The results obtained are in the form of rainfall prediction results for the next 3 years but this research uses complex equations that require a lot of time and computers with high specifications. In 2015, Handayani and Adri, predicted rainfall in Pekanbaru City using the trainlm training function with two variations, namely binary activation function and bipolar activation function [11]. The results obtained from this research are in the form of rainfall prediction results for the next 3 years, but this research uses complex equations that require a lot of time and high specifications computers.

Based on the description above, the prediction of rainfall in Pekanbaru City will be

carried out with a dynamic model using powersim. The data that will be used for rainfall prediction are temperature data, air humidity and wind speed. This research is expected to predict the monthly rainfall of Pekanbaru City for the next 3 years with simpler equations and methods.

MATERIALS AND METHODS

Collecting Data

The data used in this research is data for the last 5 years, from 2015 to 2019, totaling 240 data from 4 parametres (temperature, humidity, wind speed, and rainfall). The data was obtained from the BMKG Pekanbaru City online data website (http://dataonline.bmkg.go.id/). The data were processed and entered into monthly data in the last 5 years and the data were obtained [12-14].

Identification of System Variables

The variables used are temperature, humidity, wind speed and rainfall. The relationship between variables in the causal loop diagram of rainfall prediction in this study can be seen in Table 1 and rainfall prediction variables can be seen in Table 2.

Table 1. Relationship between variables with causal loop of rainfall prediction in Pekanbaru City.

Diagram	Variable	Connection
Rainfall	Temperature	+
	Wind velocity	–
	Air humidity	+

Table 2. Rainfall prediction variables of Pekanbaru City in 2015 – 2019.

Variable	Influencing variables	Information	Data source
Tenperature			Secondary data was obtained from BMKG Pekanbaru City
Rainfall	Wind velocity	Constant comes from BMKG	
	Air humidity		

Dynamic Model Building

Dynamic modeling is the creation of a causal loop diagram (CLD) and the creation of a stock flow diagram (SFD). Making causal loop diagrams is done by determining the factors that affect system performance. Making stock and flow diagrams is done by determining the variables affected by rainfall in Pekanbaru City against the variables that influence (temperature, humidity, and wind speed).

Dynamic Model Simulation

Simulation of dynamic model of rainfall, temperature, humidity, and wind speed of Pekanbaru City for 2015 – 2019 using powersim software tool.

Verification and Validation

Verification and validation in this research uses data in 2020 by comparing the results of rainfall simulations for the Pekanbaru City. Pekanbaru. The comparison result must be ≤ 5%, if it exceeds ≤ 5% then the causal loop diagram will be made again.

Data

Data analysis by analyzing graphs generated from Powersim Software modeling simulations. Predict rainfall for the next 3 years using Powersim by analyzing the graph result.

RESULTS AND DISCUSSION

Collecting Data

Rainfall Rate

The pattern of rainfall data that has been taken shows a seasonal cycle where in 5 years (2015 – 2019) has the same pattern. The average graph of the 5-year rainfall data of Pekanbaru City can be seen in Figure 1.

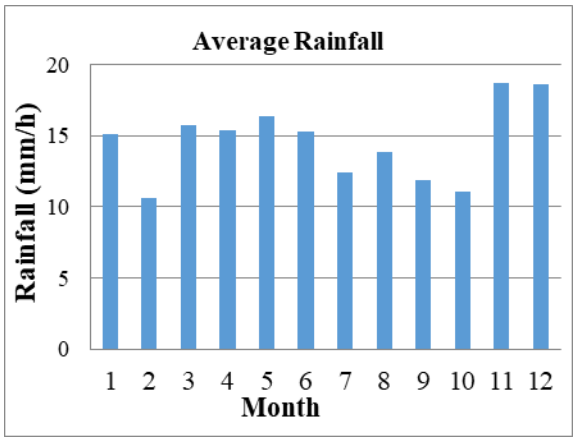

Figure 1. Graph of average rainfall monthly rainfall of Pekanbaru City in 5 years (2015 – 2019).

Air Humidity

The air humidity of Pekanbaru City shows a seasonal cycle with the highest humidity in November, and the lowest in October. The average graph of the 5-year data of air humidity of Pekanbaru City can be seen in Figure 2.

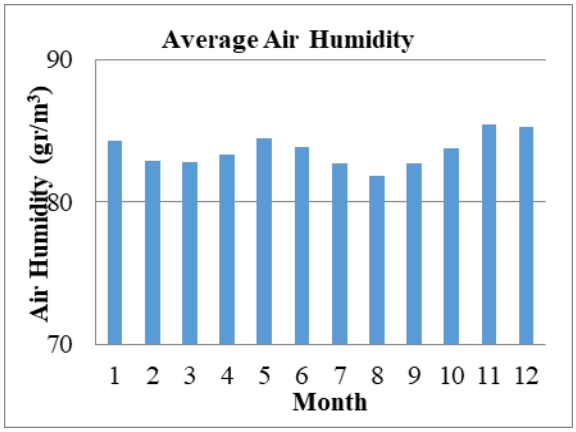

Figure 2. Graph of average monthly air humidity of Pekanbaru City in 5 years (2015 – 2019).

Temperature

The temperature of Pekanbaru City shows a seasonal cycle with the highest temperature in September, and the lowest in January. The temperature number is one of the positive variables which means, the more the temperature number increases, the more the amount of rainfall increases. The average graph of 5 years of Pekanbaru City temperature data can be seen in Figure 3.

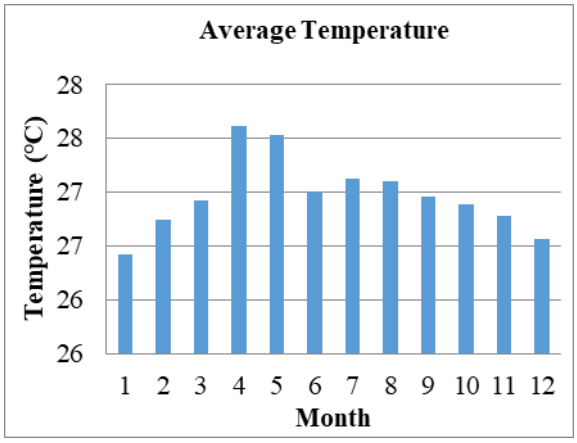

Figure 3. Graph of average monthly temperature Pekanbaru City in 5 years (2015 – 2019).

Wind Velocity

Wind speed is one of the factors that affect rainfall in Pekanbaru City. The temperature of Pekanbaru City shows a seasonal cycle with the highest humidity in September, and the lowest in January. The average graph of 5 years wind speed data of Pekanbaru City can be seen in Figure 4.

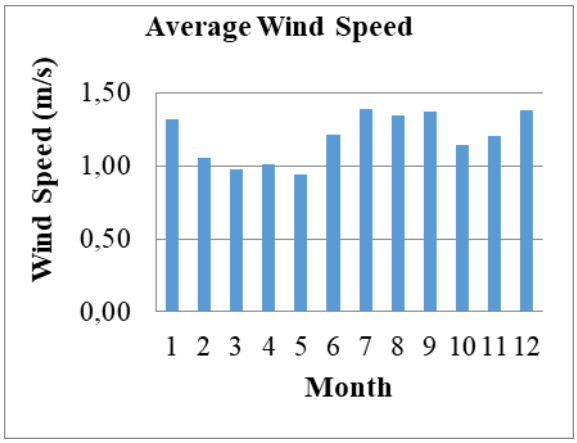

Figure 4. Graph of average monthly wind speed of Pekanbaru City in 5 years (2015 – 2019).

The temperature in November was 26.75ºC with a wind speed of 1.20 m/s which is low compared to other months. The highest temperature occurred in May which was 27.53ºC with the lowest wind speed of 0.94 m/s, rainfall at the time of the highest temperature was 16.36 mm with air humidity of 84.75 gram/m^3. The highest wind speed occurred in July which was 1.39 m/s with

rainfall of 12.42 mm, air humidity at the time of the highest temperature was 83.25 gram/m^3 and the temperature in July was 27.12ºC.

The lowest rainfall and temperature occurred in January, with rainfall of 10.13 mm and temperature of 26.42ºC. The air humidity at the time of the lowest temperature and rainfall was 84.34 gram/m^3 and the wind speed was 1.31 m/s. The lowest air humidity occurred in August which was 80.05 gram/m^3, with a wind speed of 1.35 m/s. The temperature in August was 27.10ºC and the rainfall was 13.82 mm. The average data air humidity, wind speed and temperature with rainfall for 5 years (2015 – 2019), from January to December shows the state of light rainfall, which is between 5 – 20 mm.

Results of Causal Loop Diagram of Rainfall Prediction

Causal loop diagram is made to connect variables that affect the addition and subtraction of the system model that will be used to predict the amount of rainfall in Pekanbaru City as shown in Figure 5.

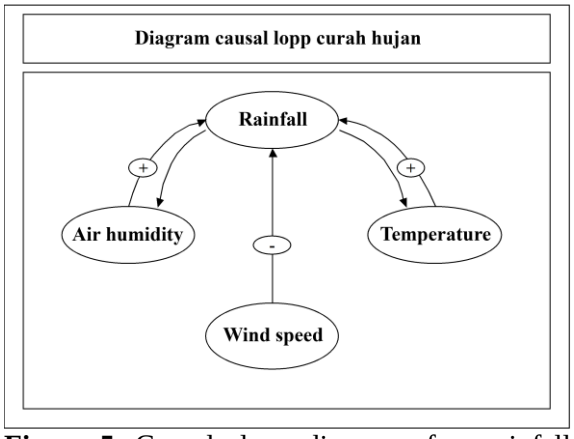

Figure 5. Causal loop diagram for rainfall prediction ini Pekanbaru City.

Factors affecting rainfall in Pekanbaru City are temperature and humidity, which are connected by a positive line, meaning that the more the temperature and humidity numbers increase, the rainfall in Pekanbaru City will also increase. Another variable that affects rainfall is wind speed which is connected with a negative line, meaning that the more the wind speed number increases, the less rainfall. The discussion above shows that the causal loop diagram is feedback information [15].

The change in air humidity in January 0.0037 is obtained from the average of the results of the change in air humidity data in 2016, 85.55 gram/m^3. 2016 85.55 gram/m^3 minus 2015 data 83.94 gram/m^3, 2017 84.50 gram/m^3 minus 2016 85.55 gram/m^3, 2018 82.60 gram/m^3 minus 2017 84.50 gram/m^3, and 2019 85.11 gram/m^3 minus 2018 82.60 gram/m^3. Changes in wind speed data and temperature data are obtained in the same way as the change data humidity.

Result of Stock Diagram Creation

Stock flow diagram is made to simulate air humidity, wind speed and temperature. Stock flow diagrams produce predictions of air humidity, wind speed and temperature which will be used to predict rainfall in Pekanbaru City for the next 2 years.

Results of Making Air Humidity Stock Flow Diagram

The stock flow diagram on the constant symbol will include the percentage of the 5-year air humidity (2015 – 2019) and on the level symbol will include the average results of the air humidity of the last 5 years (2015 – 2019). Stock flow diagram of air humidity of Pekanbaru City can be seen in Figure 6.

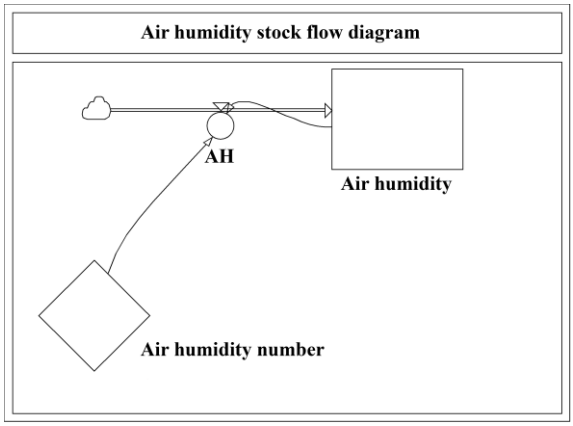

Figure 6. Stock flow diagram for air humidity prediction.

Results of Stock Flow Diagram Creation Temperature

The stock flow diagram on the constant symbol will include the percentage of the 5-year temperature (2015 – 2019) and on the level symbol will include the average results of the last 5 years of air humidity (2015 – 2019). Stock flow diagram of air humidity of Pekanbaru City can be seen in Figure 7.

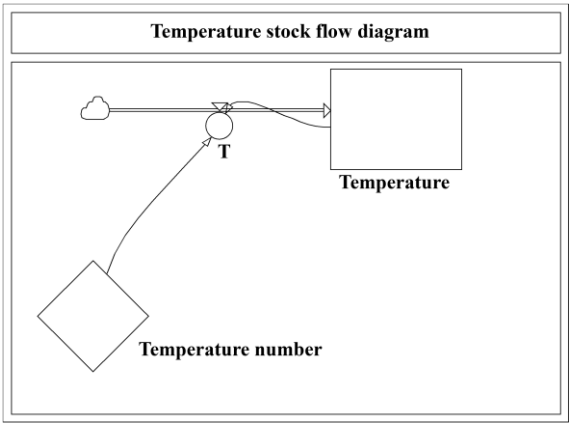

Figure 7. Stock flow diagram of temperature prediction for Pekanbaru City.

Results of Stock Flow Diagram Creation Wind Speed

The stock flow diagram on the constant symbol will include the percentage of wind speed for 5 years (2015 – 2019) and on the level symbol will include the average results of air humidity for the last 5 years (2015 – 2019). Stock flow diagram of wind speed of Pekanbaru City can be seen in Figure 8.

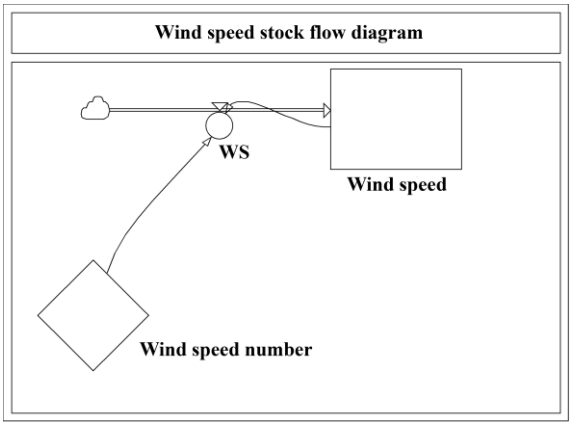

Figure 8. Stock flow diagram for predicting wind speed for Pekanbaru City.

Validation Results

Data validation results that show the percentage error does not exceed the limit ≤ 5% of the average value allowed then the prediction model made can be used. Validation of air humidity, wind Speed, and temperature of Pekanbaru City is done by comparing real data of air humidity, wind speed and temperature sourced from BMKG Pekanbaru City with simulated data [16].

Air Humidity Validation Results

Air humidity validation results when the highest simulation results are highest, namely, in July 86.69 gram/m^3 and real BMKG data from the average of the last 5 years (2015 – 2019) 82.72 gram/m^3 with an error rate of 0.0480. Air Humidity validation results when the lowest simulation results are in August 81.1 gram/m^3 and real data from BMKG from the average of the last 5 years is 81.85 gram/m^3 with an error rate of -0.0092.

Validation is made by calculating the difference between BMKG real data and simulated data, and calculating the percentage of BMKG real data. The percentage difference between the highest and lowest simulation results shows an error rate of less than ≤ 5%.

Temperature Validation Results

Temperature validation results when the highest simulation results are in July 27.07ºC, and real BMKG data from the average of the last 5 years is -0.0018. Temperature validation results at the time of the lowest simulation results in January 26.41ºC, and BMKG real data from the average of the last 5 years (2015 – 2019) is 26.42ºC with an error rate of -0.0004. Validation is made by calculating the difference between BMKG real data and simulated data, and calculating the percentage of BMKG real data. The highest and lowest simulation results show an error rate of less than ≤ 5%.

Wind Speed Validation Results

Wind speed validation results when the highest simulation results are in July 1.38 m/s and real BMKG data from the average of the last 5 years (2015 – 2019) 1.39 m/s, with an error rate of -0.01. Wind speed validation results when the lowest simulation results are in March 0.9 m/s and real BMKG data from the average of the last 5 years is 0.97 m/s with an error rate of -0.7. Validation is made by calculating the difference between BMKG real data and simulated data, and calculating the percentage of BMKG real data. The percentage difference between the highest and lowest simulation results shows an error rate of less than ≤ 5%.

The results of validation of air humidity, temperature and wind speed are in line with the results of research conducted by Nursanti in 2017, which does not exceed the ≤ 5% limit.

Prediction Results

Prediction results can be used after the simulated data is validated by comparing with real data, Air humidity wind speed and temperature have been declared valid. The percentage value of the validation error of air humidity, wind speed and temperature is within the limits of the average value allowed which is ≤ 5% [17].

Air Humidity Prediction Results

The results of the prediction of air humidity in Pekanbaru City are obtained from entering the percentage of air humidity into the stock flow diagram which can be seen in Figure 6. The highest air humidity prediction results occur in December, namely in 2020 85.46 gram/m^3, while 2021 85.48 gram/m^3 and 2022 is 85.51 gram/m3. The lowest air humidity prediction results occurred in August in 2020 81.97 gram/m^3, while in 2021 82 gram/m^3 and in 2022 82.02 gram/m^3. The predicted air humidity results have the same pattern as the BMKG real average data, which shows that the highest air humidity figure occurs in December and the lowest occurs in August.

Temperature Prediction Results

The results of the Pekanbaru City temperature prediction are obtained from entering the percentage of wind speed into the Pekanbaru City temperature stock flow diagram which can be seen in Figure 7. The highest temperature prediction results occur in April, the predicted temperature for 2020 – 2021 in that month is 27.65ºC while in 2022 it is 27.66ºC. The lowest temperature prediction results occur in January, the predicted temperature in 2020 is 26.45ºC while in 2021 and 2022 it is 26.46ºC. in that month it is 26.43ºC.

Wind Speed Prediction Results

The results of the prediction of wind speed in Pekanbaru City are obtained from entering the percentage of wind speed into the stock flow diagram which can be seen in Figure 8. The highest wind speed prediction results occur in July, the predicted wind speed for 2020 – 2022 in that month is 1.41 m/s. The lowest wind speed prediction results occurred in May, in 2020 it was 0.97 m/s while in 2021 and 2022 it was 0.98 m/s.

The BMKG real average data for the last 5 years (2015 – 2019) and the simulation results do not change too much every month, but still have differences every month with the same pattern every year. Air humidity, wind speed and temperature in the BMKG real average data for the last 5 years (2015 – 2019) show that the average rainfall is in a light rainy condition because the BMKG real average rainfall data for the last 5 years (2015 – 2019) ranges from 5 – 20 mm. Rainfall 2020-2021 is predicted to experience light rain on average, this prediction is in line with research conducted [18] which predicts based on seeing the same data patterns in the variables that influence it.

CONCLUSION

The validation results of air humidity, temperature and wind speed do not exceed the limit of ≤ 5% of the average value allowed. The validation results on simulated data with real BMKG data are declared valid because they do not exceed the predetermined limit of ≤ 5%. Rainfall in 2020 – 2021 is predicted to experience light rain on average.

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