**PREDICTION OF MONTHLY RAINFALL WITH MONTE CARLO SIMULATION IN MEDAN CITY AREA**

Arini1,Hendra Cipta2 **1,2**Program Studi Matematika, Fakultas Sains Dan Teknologi, Universitas Islam Negeri Sumatera Utara,Medan, Indonesia
Email: 1arini0703201013@uinsu.ac.id, 2 hendracipta@uinsu.ac.id

***Abstract*—** **Medan City has relatively high and variable rainfall throughout the year, with an average monthly rainfall of about 150-300 mm in the wet season and 50-100 mm in the dry season. Data shows that in 2021 there will be high rainfall in January and November, in 2022 is stable with a peak in November.From the simulations that have been carried out, the overall accuracy of the simulation in 2021 has Y Error of (0.60%), X1 Air temperature (3.04%), X2 Wind speed (30. 28%), X3 Air humidity (3.09%), X4 Solar irradiation intensity (13.31%), In 2022 Y (0.65%), X1 (11.76%), X2 (18.72%), 0.20%), and in 2023 where Y error (0.72%), X1 (2.58%), X2 (15. 23%), X3 (5.05%), X4 (35.92%), From the results conducted by the author to predict the nature of monthly rainfall using the Monte Carlo simulation method in the Medan city area which has a MAPE accuracy test result of 12.28%, the test results come from the average calculation performed on the Monte Carlo method prediction with 5 different variables at each stage.**

**Keywords: Rainfall, Monte Carlo Simulation, nature of rainfall, accuracy test results, prediction**

***Abstrak*—** **Kota Medan memiliki curah hujan yang relatif tinggi dan bervariasi sepanjang tahun, dengan rata-rata curah hujan bulanan sekitar 150-300 mm pada musim hujan dan 50-100 mm pada musim kemarau. Data menunjukkan tahun 2021 akan terjadi curah hujan tinggi pada bulan Januari dan November, tahun 2022 stabil dengan puncaknya pada bulan November. Metode Simulasi Monte CarloDari simulasi yang telah dilakukan, secara keseluruhan akurasi simulasi .pada tahun 2021 memiliki Y Error sebesar (0,60%), X1 Suhu udara (3,04%), X2kecepatan angin (30,28%), X3 Kelembapan udara (3,09%), X4 Isensitas Radiasi cahaya (13,31%), Pada tahun 2022 Y(0,65%), X1(11,76%), X2(18,72%), 0,20%), dan pada tahun 2023 dimana Y berada kesalahannya adalah (0,72%), X1 (2,58%), X2(15,23% ), X3(5,05%), X4(35,92%), Dari hasil penelitian yang dilakukan penulis untuk memprediksi sifat curah hujan bulanan dengan menggunakan metode simulasi Monte Carlo di wilayah tersebut. Wilayah kota Medan yang mempunyai hasil uji akurasi MAPE 12,28% hasil pengujian tersebut berasal dari rata-rata perhitungan yang dilakukan terhadap prediksi metode Monte Carlo dengan 5 variabel berbeda pada setiap tahapannya.

Kata kunci: Curah Hujan, Simulasi Monte Carlo, Sifat curah hujan, Hasil Uji Akurasi, Prediksi**

# Introduction

North Sumatra Province is located on the island of North Sumatra with coordinates of 1° - 4°N and 98° - 100°E. Its strategic location around the equator and crossed by the Bukit Barisan Mountains, and flanked by the Strait of Malacca and the Indian Ocean, affect its climate[1]. Rainfall in the province is influenced by global phenomena such as the Indian Ocean Dipole (IOD), Inter Tropical Convergence Zone (ITCZ), Madden Julian Oscillation (MJO), and El Niño (ENSO), as well as regional climatic factors such as monsoons and tropical disturbances. Local factors such as natural conditions and solar movements also affect rainfall in this area [2].Rainfall in the light category is generally in the form of drizzle or short rains. The normal category is heavier than light rain and is able to wet the ground evenly. Heavy rain can cause standing water and potential flooding in poorly drained areas, while very heavy rain is often accompanied by thunderstorms and can cause flooding, landslides and infrastructure damage. To predict rainfall in a place, the Monte Carlo simulation method is used [3]

Rainfall in Medan City is an important parameter in hydrological and meteorological studies, as it plays a major role in determining flood risk and environmental damage. The city has monthly rainfall ranging from 150-300 mm in the wet season and 50-100 mm in the dry season. Rainfall is measured by observatories and expressed in millimetres. One millimetre of rain means one litre of water per square metre of flat ground[4].Predictive data on rainfall and air humidity are taken from observations at the BMKG. BMKG collects all climatological parameters to study weather conditions and process data for prediction. The large amount of data often leads to prediction errors, especially the analysis of rainfall and humidity. An appropriate prediction method is needed to predict monthly rainfall and humidity[5].Although rainfall cannot be determined with certainty, predictions can be made using historical data. One method that can be used is the Monte Carlo method, where the more simulations performed, the more convergent the prediction results [6]

# Ease of Use

* 1. Prediction

Prediction or forecasting is a business function activity that estimates the sales and usage of products so that they can be made in the right quantities. Forecasting is an estimate of future demand based on several forecasting variables, which are based on taking past data and placing it into the future in the form of a mathematical model.[7]

## Rainfall Rate

Rainfall is one of the weather elements whose data is obtained by measuring it using a rain gauge, so that the amount can be known in millimetres (mm). 1mm of rainfall is the amount of rainwater that falls on the surface per unit area (m2) with a record of nothing evaporating, soaking or flowing. so rainfall of 1mm is equivalent to 1liter/𝑚2 .

The classification of monthly rainfall according to BMKG is[8]:
a. Low 0-100mm/month

b. Medium 100-300 mm/month

c. High 300-500 mm/month

d. Very Heavy > 500 mm/month

##  Properties of Rain

Rain in the tropics generally consists of convection rain, frontal rain, and orographic rain.Forecasting is a method of predicting future events based on past data. Monte Carlo simulation is a statistical technique for estimating the solution of quantitative problems by a process of randomising data.[9]
 *C. Monte carlo simulation steps*

This method is used in systems that involve probabilities, with randomisation of variables to produce predictive results.[10]

* 1. Probability distribution

A probability distribution is calculated by dividing the frequency of an event by the total frequency:

 $P\_{i}$=$ \frac{F\_{i}}{n}$ (2.1)
Description:
Pi= Probability distribution

F𝑖 = Frequency

n = Total frequency

* 1. Cumulative probability distribution

The cumulative distribution is obtained by summing the current probability with previous cumulative values

𝑃*K =* 𝐻*PK +* 𝑃 (2.2)

Description:

PK = Cumulative probability

HPK = Previous cumulative result

P = Next probability distribution

* 1. Determination of random number intervals

each value in the probability distribution is assigned a random number. The initial limit value of the first variable is 0, and subsequent limits are calculated by multiplying the cumulative probability by 100.[11]

* 1. Random number generation (rng)

Random numbers are generated using the linear congruence method (lcm)[12]:

 Zi= (𝑎. 𝑍𝑖 - 1 + 𝐶) Mod m (2.3)

Description:

Zi = i-th number value

Zi-1 = initial number (integer >=0, Z0<M)

a = Multiplier constant (a < m)

c = Shift constant (c < m)

m = Modulus constant (m > 0)

* 1. Mean absolute percentage error (mape)

mape measures prediction accuracy as the percentage error between actual and predicted data:

MAPE$ =\frac{\sum\_{t=1}^{n}\left|\left(\frac{A\_{t}-F\_{t}}{A\_{t}}\right)\right|x100}{n}$ (2.4)

Where:
n = Number of Periods

A𝑡 = Actual data in period t

F𝑡 = Predicted value in period t

Interpretation of mape:

1. <10% = very good
2. 10-20% = good
3. 20-50% = reasonable

4. 50% = inaccurate

The smaller the mape value, the more accurate the prediction.[13]

1. RESEARCH METHODS

This research uses data from the BMKG station in Medan City, the data used is taken from 2021-2023, while predictions are made for data for 2024-2026. The dependent variable (Y) is rainfall, while the independent variables (X1-X4) include air temperature, air pressure, air humidity, wind speed, and solar radiation intensity.[14]

Table 3.1. Initial Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Moon** | **Rainfall** | **Temperatures** | **Wind Speed** | **Air Humidity** | **Light Intensity** |
|  |  |  |  |  |
| **(Y)** | **(X1)** | **(X2)** | **(X3)** | **(X4)** |
| **Jan (2021)** | 518,3 | 26,5 | 1,12 | 86 | 2,09 |
| **Feb** | 87,9 | 27,8 | 1,57 | 80 | 5,14 |
| **Mar** | 222,7 | 27,7 | 1,32 | 82 | 3,84 |
| **Apr** | 300,2 | 27,7 | 1,3 | 83 | 2,97 |
| **May** | 158 | 28,2 | 1,25 | 83 | 3,73 |
| **Jun** | 243,8 | 27,8 | 1,23 | 81 | 4,01 |
| **Jul** | 193,7 | 28 | 1,22 | 80 | 4,99 |
| **Aug** | 295,2 | 27,6 | 1 | 84 | 2,65 |
| **Sept** | 287,1 | 28,3 | 1,66 | 82 | 3,42 |
| **Oct** | 257,7 | 29 | 1,77 | 79 | 327,3 |
| **Nov** | 497,4 | 27,7 | 1,6 | 85 | 3,68 |
| **Des** | 189,2 | 27,5 | 1,64 | 86 | 3,47 |
| **Jan (2022)** | 181 | 28,1 | 1,61 | 83 | 3,95 |
| **Feb** | 334,8 | 27,8 | 1,42 | 85 | 3,33 |
| **Mar** | 191,2 | 29,3 | 1,77 | 82 | 5,04 |
| **Apr** | 184,2 | 29,6 | 1,5 | 83 | 4,26 |
| **May** | 125,5 | 29,4 | 1,29 | 85 | 4,55 |
| **Jun** | 313,4 | 28,9 | 1,2 | 84 | 4,11 |
| **Jul** | 165,9 | 29,5 | 1,83 | 81 | 4,88 |
| **Aug** | 505,1 | 28,8 | 1,8 | 84 | 3,98 |
| **Sept** | 308,2 | 28,2 | 2 | 82 | 3,27 |
| **Oct** | 321,5 | 27,5 | 1,51 | 86 | 2,45 |
| **Nov** | 525,9 | 26,8 | 1,56 | 88 | 3,1 |
| **Des** | 321,2 | 26,1 | 1,7 | 88 | 2,15 |
| **Jan (2023)** | 164,5 | 26,5 | 1,93 | 85 | 3,2 |
| **Feb** | 163,2 | 27 | 1,71 | 85 | 4,27 |
| **Mar** | 193,5 | 27,3 | 1,77 | 85 | 4,75 |
| **Apr** | 196,1 | 27,9 | 1,56 | 85 | 5,14 |
| **May** | 189,1 | 28,6 | 1,61 | 83 | 4,97 |
| **Jun** | 348,4 | 28,3 | 1,3 | 84 | 4,7 |
| **Jul** | 196,8 | 28,2 | 1,32 | 84 | 4,73 |
| **Aug** | 606,6 | 27,4 | 1,54 | 87 | 3,44 |
| **Sept** | 577,5 | 27,5 | 1,53 | 86 | 3,05 |
| **Oct** | 278 | 27,4 | 1,45 | 87 | 3,09 |
| **Nov** | 183,6 | 27,2 | 1,73 | 87 | 3,1 |
| **Des** | 335,5 | 27 | 1,48 | 88 | 1,78 |
| **Sum** | **10162** | **1004** | **54,8** | **3028** | **458,6** |

Source: Meteorology, Climatology and Geophysics Agency Region 1[15]

1. Results and Discussion

This study calculates the prediction of monthly rainfall properties with Monte Carlo simulation in the city of Medan using the above data samples. In the step of generating random numbers, the Monte Carlo method calculation uses five different variables. The following are the steps taken in the research.

a. determine the probability distribution with equation (2.1)

Y1= 518,3/10161,9 = 0,05 Y7 = 193,7/10161,9 = 0,01
Y2= 87,9/10161,9 = 0,00 Y8 = 295,2/10161,9 = 0,02
Y3=222,7/10161,9 = 0,02 Y9 = 287,1/10161,9 = 0,02

Table 3.2. Pobability distribution

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Moon** |  **(Y)** | **Pro** | **(X1)** | **Pro** | **(X2)** | **Pro** |
| **Jan (2021)** | 518,3 | 0,05 | 26,5 | 0,02 | 1,12 | 0,02 |
| **Feb** | 87,9 | 0 | 27,8 | 0,02 | 1,57 | 0,02 |
| **Mar** | 222,7 | 0,02 | 27,7 | 0,02 | 1,32 | 0,02 |
| **April** | 300,2 | 0,02 | 27,7 | 0,02 | 1,3 | 0,02 |
| **Okt (2023)** | 278 | 0,02 | 27,4 | 0,02 | 1,45 | 0,02 |
| **Nov** | 183,6 | 0,01 | 27,2 | 0,02 | 1,73 | 0,03 |
| **Des** | 335,5 | 0,03 | 27 | 0,02 | 1,48 | 0,02 |
| **Sum** | **10162** | **0,78** | **1004** | **1,73** | **54,8** | **0,82** |

|  |  |  |  |
| --- | --- | --- | --- |
| **(X3)** | **Pro** |  **(X4)** | **Pro** |
| 86 | 0,02 | 2,09 | 0 |
| 80 | 1,45 | 5,14 | 0 |
| 82 | 0,02 | 3,84 | 0 |
| 83 | 0,02 | 2,97 | 0 |
| 87 | 0,02 | 3,09 | 0 |
| 87 | 0,02 | 3,1 | 0 |
| 88 | 0,02 | 1,78 | 0 |
| **3028** | **2,15** | **458,6** | **0,8** |

1. determine the cumulative distribution with equation (2.2) PK1 = 0,05 PK7=0,12+0,01=0,13
PK2 = 0,05+0,00 = 0,05 PK8=0,13+0,02=0,15
PK3 = 0,05+0,02 = 0,07 PK9=0,15+0,0 = 0,17

Table 3.2. Cumulative Distribution

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Moon** |  **(Y)** | **Pro** | **Cum** |  **(X1)** | **Pro** | **Cum** |
| **Jan (2021)** | 518,3 | 0,05 | 0,05 | 26,5 | 0,02 | 0,02 |
| **Feb** | 87,9 | 0 | 0,05 | 27,8 | 0,02 | 0,04 |
| **Mar** | 222,7 | 0,02 | 0,07 | 27,7 | 0,02 | 0,06 |
| **Apr** | 300,2 | 0,02 | 0,09 | 27,7 | 0,02 | 0,08 |
| **Oct (2023)** | 278 | 0,02 | 0,74 | 27,4 | 0,02 | 1,69 |
| **Nov** | 183,6 | 0,01 | 0,75 | 27,2 | 0,02 | 1,71 |
| **Des** | 335,5 | 0,03 | 0,78 | 27 | 0,02 | 1,73 |
| **Sum** | **10162** | **0,78** |  | **1004** | **1,73** |  |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Moon** | **(X3)** | **Pro** | **Cum** | **(X4)** | **Pro** | **Cum** |
|
| **Jan(2021)** | 86 | 0,02 | 0,02 | 2,09 | 0 | 0 |
| **Feb** | 80 | 1,45 | 1,47 | 5,14 | 0,01 | 0,01 |
| **Mar** | 82 | 0,02 | 1,49 | 3,84 | 0 | 0,01 |
| **Apr** | 83 | 0,02 | 1,51 | 2,97 | 0 | 0,01 |
| **Oct(2023)** | 87 | 0,02 | 2,11 | 3,09 | 0 | 0,8 |
| **Nov** | 87 | 0,02 | 2,13 | 3,1 | 0 | 0,8 |
| **Des** | 88 | 0,02 | 2,15 | 1,78 | 0 | 0,8 |
| **Sum** | **3028** | **2,15** |   | **458,61** | **0,8** |  |

1. Determining the random interval

 Assign random interval numbers starting from zero for the first number of random interval numbers and the final number based on the results of the distribution of the commulation.

Table 3.3. Random intervals

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **Cum**  | **Intervals** | **Cum** | **Intervals** |
| **(Y)** | **(X1)** |
| **Jan(2021)** | 0,05 | 0-5 | 0,02 | 0-2 |
| **Feb** | 0,05 | 05-05 | 0,04 | 03-04 |
| **Mar** | 0,07 | 06-06 | 0,06 | 05-06 |
| **Apr** | 0,09 | 08-09 | 0,08 | 07-08 |
| **Oct(2023)** | 0,74 | 73-74 | 1,69 | 168-169 |
| **Nov** | 0,75 | 75-75 | 1,71 | 170-171 |
| **Dec** | 0,78 | 76-78 | 1,73 | 172-173 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **Cum** | **Intervals** | **Cum** | **Intervals** |
| **(X2)** | **(X3)** |
| **Jan(2021)** | 0,02 | 0-2 | 0,02 | 0-2 |
| **Feb** | 0,04 | 03-04 | 1,47 | 3-147 |
| **Mar** | 0,06 | 05-06 | 1,49 | 148-149 |
| **Apr** | 0,08 | 07-08 | 1,51 | 150-151 |
| **Oct(2023)** | 0,77 | 76-77 | 2,11 | 210-211 |
| **Nov** | 0,8 | 78-80 | 2,13 | 212-213 |
| **Dec** | 0,82 | 81-82 | 2,15 | 214-215 |

|  |  |
| --- | --- |
| **Cum****(X4)** | **Intervals** |
| 0 | 0 |
| 0,01 | 0-1 |
| 0,01 | 1-1 |
| 0,01 | 1-1 |
| 0,8 | 80-80 |
| 0,8 | 80-80 |
| 0,8 | 80-80 |

Pada tabel di atas, interval angka acak ditentukan dari nilai probabilitas kumulatif sebelumnya. Fungsi angka acak adalah sebagai pembatas antara variabel yang berfungsi sebagai acuan hasil simulasi.

1. Generating random numbers

Before generating random numbers, random number intervals must be available. This research uses the mixed congruence method, which requires 4 parameters: a, c, m, and Z0. Random numbers are generated using the formula equation (2.3)

Rainfall (Y)

$Z\_{I-1}$**= 7** $Z\_{1}=\left(32x7+9\right)mod99=35$
**a=32**  $Z\_{2}=\left(32X35+9\right)mod99=40$
**c=9** $Z\_{3}=\left(32X40+9\right)mod99=2$
**m=99**

Table 3.4.Generating random numbers

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **Intervals** | **R.****Numbers** | **Intervals** | **R.****Numbers** |
| **(Y)** | **(X1)** |
| **Jan(2021)** |   | 35 | 0-2 | 142 |
| 0-5 |
| **Feb** | 05-05 | 40 | 03-04 | 104 |
| **Mar** | 06-07 | 2 | 05-06 | 85 |
| **Apr** | 08-09 | 73 | 07-08 | 175 |
| **Oct(2023)** | 73-74 | 73 | 168-169 | 162 |
| **Nov** | 75-75 | 68 | 170-171 | 114 |
| **Dec** | 76-78 | 7 | 172-173 | 90 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **Intervals** | **R.****Numbers** | **Intervals** | **R.****Numbers** |
| **(X2)** | **(X3)** |
| **Jan(2021)** | 0-2 | 46 | 0-2 | 159 |
| **Feb** | 03-04 | 19 | 3-147 | 120 |
| **Mar** | 05-06 | 73 | 148-149 | 50 |
| **Apr** | 07-08 | 64 | 150-151 | 6 |
| **Oct(2023)** | 76-77 | 64 | 210-211 | 148 |
| **Nov** | 78-80 | 82 | 212-213 | 187 |
| **Dec** | 81-82 | 46 | 214-215 | 58 |

|  |  |
| --- | --- |
| **Interval** | **R.****Numbers** |
| **(X4)** |
| 0 | 46 |
| 0-1 | 79 |
| 01-Jan | 79 |
| 01-Jan | 79 |
| 80-80 | 79 |
| 80-80 | 79 |
| 80-80 | 79 |

1. Determining Mape Validity Test with equation (2.4)

Year 2021
MAPE$ =\frac{\sum\_{t=1}^{n}\left|\left(\frac{A\_{t}-F\_{t}}{A\_{t}}\right)\right|x100}{n}$

MAPE = $\frac{\left|\left(\frac{A\_{1}-F\_{1}}{A\_{1}}\right)+\left(\frac{A\_{2}-F\_{2}}{A\_{2}}\right)+…+\left(\frac{A\_{12}-F\_{12}}{A\_{12}}\right)X100\right|}{12}$

MAPE = $\frac{\left|\left(\frac{518,3-165,9}{518,3}\right)+\left(\frac{87,9-308,2}{87,9}\right)+…+\left(\frac{189,2-222,7}{189,2}\right)X100\right|}{12}$

MAPE =$ \frac{67,99+\left(-250\right)+…+0,17}{12}$

MAPE = $\frac{8}{12}$ = 0,66%

Table 3.5.MAPE Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(Y)** | **(X1)** |
| **Jan** | 165,9 | 0,6799 | 28,2 | 0,0642 |
| **Feb** | 308,2 | 2,5063 | 28,2 | 0,0144 |
| **Mar** | 518,3 | 1,3273 | 28,2 | 0,0181 |
| **Nov** | 577,5 | 0,161 | 26,5 | 0,0433 |
| **Des** | 222,7 | 0,1771 | 28,2 | 0,0255 |
|  | **MAPE** | **0,667** |  | **3,0438** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(X2)** | **(X3)** |
| **Jan** | 84 | 0,0233 | 84 | 0,0233 |
| **Feb** | 80 | 0 | 80 | 0 |
| **Mar** | 80 | 0,0244 | 80 | 0,0244 |
| **Nov** | 80 | 0,0588 | 80 | 0,0588 |
| **Des** | 80 | 0,0698 | 80 | 0,0698 |
|  |  | **3,091** |  | **3,0905** |

|  |  |
| --- | --- |
| **S.result** | **MAPE** |
| **(X4)** |  |
| 327,3 | 155,617 |
| 4,7 | 0,0856 |
| 4,7 | 0,22396 |
| 4,7 | 0,27717 |
| 4,7 | 0,35447 |
|  | **13,314** |

## Year 2022

MAPE$ =\frac{\sum\_{t=1}^{n}\left|\left(\frac{A\_{t}-F\_{t}}{A\_{t}}\right)\right|x100}{n}$

MAPE = $\frac{\left|\left(\frac{A\_{1}-F\_{1}}{A\_{1}}\right)+\left(\frac{A\_{2}-F\_{2}}{A\_{2}}\right)+…+\left(\frac{A\_{12}-F\_{12}}{A\_{12}}\right)X100\right|}{12}$

MAPE = $\frac{\left|\left(\frac{181-165,9}{181}\right)+\left(\frac{334,8-308,2}{334,8}\right)+…+\left(\frac{321,2-222,7}{321,2}\right)X100\right|}{12}$

MAPE =$ \frac{0,08+0,07+0,30}{12}$

MAPE = $\frac{7,88}{12}$ = 0,65%

Table 3.6 MAPE Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(Y)** | **(X1)** |
| **Jan** | 165,9 | 0,0834 | 26,1 | 0,0712 |
| **Feb** | 308,2 | 0,0795 | 27,7 | 0,0036 |
| **Mar** | 518,3 | 1,7108 | 28,2 | 0,0375 |
| **Nov** | 577,5 | 0,0981 | 28,2 | 0,0522 |
| **Des** | 222,7 | 0,3067 | 28,2 | 0,0805 |
|  |  | **0,657** |  | **11,767** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(X2)** | **(X3)** |
| **Jan** | 1,54 | 0,0435 | 80 | 0,03615 |
| **Feb** | 1,56 | 0,0986 | 80 | 0,05882 |
| **Mar** | 1,48 | 0,1638 | 86 | 0,04878 |
| **Nov** | 1,54 | 0,0128 | 79 | 0,10227 |
| **Des** | 1,56 | 0,0824 | 80 | 0,09091 |
|  |  | **15,73** |  | **8,0218** |

|  |  |
| --- | --- |
| **S.result** | **MAPE** |
| **(X4)** |  |
| 4,7 | 0,18987 |
| 4,7 | 0,41141 |
| 4,7 | 0,06746 |
| 4,7 | 0,51613 |
| 4,7 | 1,18605 |
|  | **35,202** |

Year 2023

MAPE$ =\frac{\sum\_{t=1}^{n}\left|\left(\frac{A\_{t}-F\_{t}}{A\_{t}}\right)\right|x100}{n}$

MAPE = $\frac{\left|\left(\frac{A\_{1}-F\_{1}}{A\_{1}}\right)+\left(\frac{A\_{2}-F\_{2}}{A\_{2}}\right)+…+\left(\frac{A\_{12}-F\_{12}}{A\_{12}}\right)X100\right|}{12}$

MAPE = $\frac{\left|\left(\frac{164,5-165,9}{164,5}\right)+\left(\frac{163,2-308,2}{163,2}\right)+…+\left(\frac{335,5-222,7}{335,5}\right)X100\right|}{12}$

MAPE =$ \frac{-0,08+(-0,88+0,33}{12}$

MAPE = $\frac{8,69}{12}$ = 0,72%

Table 3.7 MAPE Results

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(Y)** | **(X1)** |
| **Jan** | 165,9 | 0,0085 | 28,2 | 0,0642 |
| **Feb** | 308,2 | 0,8885 | 27,4 | 0,0148 |
| **Mar** | 518,3 | 1,6786 | 28,2 | 0,033 |
| **Nov** | 577,5 | 2,1454 | 28 | 0,0294 |
| **Des** | 222,7 | 0,3362 | 28,2 | 0,0444 |
|  |  | **0,724** |  | **2,5889** |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Moon** | **S.result** | **MAPE** | **S.result** | **MAPE** |
| **(X2)** | **(X3)** |
| Jan | 1,48 | 0,23316 | 80 | 0,059 |
| Feb | 2 | 0,16959 | 80 | 0,059 |
| Mar | 1,77 | 0 | 85 | 0 |
| Nov | 1,48 | 0,14451 | 86 | 0,011 |
| Des | 2 | 0,35135 | 80 | 0,091 |
|  |   | **15,2321** |  | **5,052** |

|  |  |
| --- | --- |
| **S.result** | **MAPE** |
| **(X4)** |  |
| 4,7 | 0,469 |
| 4,7 | 0,101 |
| 4,7 | 0,011 |
| 4,7 | 0,516 |
| 4,7 | 1,64 |
|  | **35,93** |

From the simulations that have been carried out, the overall simulation accuracy from 2021 Rainfall (0.66%), Air Temperature (3.04%) Wind Speed (30.28%), Air Humidity (3.09%), Light Radiation Intensity (13.31%), 2022 Rainfall (0.65%), Air Temperature (11.76%) Wind Speed (15.72%), Air Humidity (8.02%), Light Radiation Intensity (35.20%), and year 2023 Rainfall (0.72%), Air Temperature (2.58%) Wind Speed (15.23%), Air Humidity (5.05%), Light Radiation Intensity (35.92%).

1. Prediction Results

Table 3.8 Prediction Results

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Moon** | **(Y)** | **(X1)** | **(X2)** | **(X3)** | **(X4)** |
| **Jan (2024)** | 165,9 | 28,2 | 2 | 84 | 327,33 |
| **Feb** | 308,2 | 28,2 | 1,77 | 80 | 4,7 |
| **Mar** | 518,3 | 28,2 | 1,54 | 80 | 4,7 |
| **Apr** | 278 | 27 | 1,56 | 80 | 4,7 |
| **Mei** | 577,5 | 28,2 | 1,48 | 80 | 4,7 |
| **Jun** | 222,7 | 28,2 | 2 | 80 | 4,7 |
| **Jul** | 165,9 | 27,7 | 1,77 | 80 | 4,7 |
| **Agust** | 308,2 | 29,4 | 1,54 | 80 | 4,7 |
| **Sept** | 308,2 | 26,5 | 1,56 | 80 | 4,7 |
| **Okt** | 278 | 29,6 | 1,48 | 82 | 4,7 |
| **Nov** | 577,5 | 26,5 | 2 | 80 | 4,7 |
| **Dec** | 222,7 | 28,2 | 1,77 | 80 | 4,7 |
| **Jan (2025)** | 165,9 | 26,1 | 1,54 | 80 | 4,7 |
| **Feb** | 308,2 | 27,7 | 1,56 | 80 | 4,7 |
| **Mar** | 518,3 | 28,2 | 1,48 | 86 | 4,7 |
| **Apr** | 278 | 26,5 | 2 | 80 | 4,7 |
| **May** | 577,5 | 2,82 | 1,77 | 80 | 4,7 |
| **Jun** | 222,5 | 28,9 | 1,54 | 80 | 4,7 |
| **Jul** | 165,9 | 26,2 | 1,56 | 85 | 4,7 |
| **Agus** | 308,2 | 28,2 | 1,48 | 86 | 4,7 |
| **Sept** | 518,3 | 28,2 | 2 | 80 | 4,7 |
| **Okt** | 278 | 28,2 | 1,77 | 80 | 4,7 |
| **Nov** | 577,5 | 28,2 | 1,54 | 79 | 4,7 |
| **Des** | 222,7 | 28,2 | 1,56 | 80 | 4,7 |
| **Jan (2026)** | 165,9 | 28,2 | 1,48 | 80 | 4,7 |
| **Feb** | 308,2 | 27,4 | 2 | 80 | 4,7 |
| **Mar** | 518,3 | 28,2 | 1,77 | 85 | 4,7 |
| **Aprl** | 278 | 28,2 | 1,54 | 81 | 4,7 |
| **May** | 577,5 | 27 | 1,56 | 80 | 4,7 |
| **Jun** | 222,7 | 28,2 | 1,48 | 80 | 4,7 |
| **July** | 155,9 | 28,2 | 2 | 80 | 4,7 |
| **Agus** | 308,2 | 28,2 | 1,77 | 80 | 4,7 |
| **Sept** | 518,3 | 28,2 | 1,54 | 80 | 4,7 |
| **Okt** | 278 | 27,4 | 1,56 | 82 | 4,7 |
| **Nov** | 577,5 | 28 | 1,48 | 86 | 4,7 |
| **Des** | 222,7 | 28,2 | 2 | 80 | 4,7 |

Conclusions

This research calculates the prediction of monthly rainfall properties using Monte Carlo simulation in Medan city area. To complete this research there are several steps that we must do, the first is to determine the probability distribution in equation (2.1) which means collecting monthly rainfall data from the previous period. The second is the cumulative distribution, where the cumulative distribution is calculated by summing the current probability with the previous probability. The third is the random interval, where this interval is used to determine rainfall based on random numbers that will be generated later. Fourth, to generate random numbers, this method requires 4 parameters whose values must be determined first, namely a, c, m, Z0, to generate random numbers, the last is to determine the MAPE validity test, where the calculation produces each variable. in 2021 has Y Error of (0.60%), X1 Air temperature (3.04%), X2 wind speed (30.28%), X3 Air humidity (3.09%), X4 Light radiation intensity (13.31%), In 2022 Y (0.65%), X1 (11.76%), X2 (18.72%), 0.20%), and in 2023 where Y is the error is (0.72%), X1 (2.58%), X2 (15.23%), X3 (5.05%), X4 (35.92%). From the results of the research conducted by the author for the prediction of monthly rainfall properties with the Monte Carlo simulation method in the Medan city area, there are MAPE test results of 12.28%, the test results come from the average calculation performed on the Monte Carlo method prediction with 5 different variables at each stage. And MAPE testing to determine the error value. This method was successfully applied to predict the nature of monthly rain in the city of Medan with fairly good results.

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