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Research Paper

Prediction Of Rainfall And Temperature In Semarang City For The Period Of 2025-2050 Using The Arima Model

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Abstract*:Global climate change has a real impact on a local scale, including urban areas such as Semarang City which are vulnerable to floods, droughts, and the Urban Heat Island (UHI) phenomenon. Therefore, a study is needed to project rainfall and temperature conditions in the future. This study aims to project the trend of rainfall and temperature in Semarang City in the period 2025–2050 using the ARIMA (AutoRegressive Integrated Moving Average) method based on historical data from 2001–2024 which has gone through a bias correction process, and presents it in the form of a spatial map. The analysis was carried out at three BMKG stations (Central Java, Tanjung Emas, and Ahmad Yani Stations). The results showed that rainfall tended to increase with more even spatial redistribution, while air temperature also increased at maximum and minimum temperatures throughout the region. Spatial maps show that the southern region remains relatively warmer and wetter than the warmer and humider northeast, with a tendency to shift in temperature and precipitation classes over time. These findings indicate the impact of local climate change that needs to be considered in water resource management and urban adaptation planning.*
Key words :*ARIMA, climate prediction, rainfall, temperature, Semarang*

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I. Introduction

Climate change is a global challenge that has a significant impact on the environment, economy, and natural resources. This phenomenon is characterized by an increase in global temperatures, changes in rainfall patterns, and an increasing frequency of extreme weather events such as heat waves and tropical storms [1]. Studies in various regions show an annual increase in temperature of up to 2°C and a change in rainfall patterns [2]. This condition underscores the importance of accurate climate monitoring and modeling efforts to predict the impact of climate change in the future.

Based on news published by bnpb.go.id online media, Semarang City is an area that is vulnerable to the impact of climate change. This city often experiences extreme weather events such as flash floods, high-intensity rain, and extreme hot temperatures. Therefore, accurate scientific studies based on climate data are needed to understand the dynamics of rainfall and air temperature in this region. One commonly used data source is reanalysis data, but this data often contains biases or systematic differences between model results and observations. To increase its reliability, a bias correction process is carried out using various methods such as linear scaling and distribution mapping [3] [4].

The bias correction method can be carried out using Climate Model data for hydrologic modelling (CMhyd) software which is effective in adjusting climate simulation data to observation conditions. Various studies prove that CMhyd is able to improve the accuracy of temperature and precipitation data [5]. Nevertheless

its application in Indonesia, especially in the city of Semarang, is still limited. Therefore, this study was conducted to analyze the effectiveness of the bias correction method on reanalysis climate data and produce rainfall and temperature projections that are more representative of local conditions.

In addition to bias correction, the AutoRegressive Integrated Moving Average (ARIMA) model is used to analyze and project future climate trends [6]. This model has been shown to be effective in predicting trends and analyzing the spatial characteristics of rainfall, with predictive results consistent with actual data [7]. By combining the CMhyd bias correction method and the ARIMA statistical model, this study aims to obtain a more accurate projection of rainfall and air temperature for the 2025–2050 period in Semarang City. The results of the research are expected to be a scientific basis in planning for climate change adaptation and mitigation in urban areas.

II. Method

Research Procedure

The research procedures carried out began from data collection, analysis of evaluation and validation of bias correction, ARIMA projection, and spatial map projection.

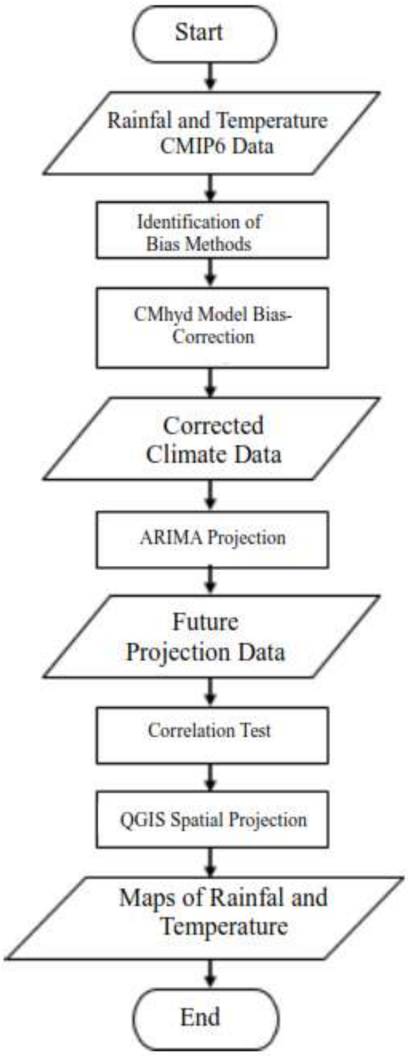

Figure 1. Research Flow Diagram

Analysis, Evaluation, and Validation of Bias Correction

Rainfall and temperature data that have been collected, plotted according to a time series from a 24-year time span from January 2001 to December 2024. The data is then used as input to the CMhyd software to correct its bias by applying linear scaling and distribution mapping methods, respectively for each weather parameter, namely rainfall and temperature to align the model output with the actual data. Evaluate and validate the results of bias correction by comparing reanalysis data before and after correction of observation data, using statistical indicators, namely RMSE, R^2, PBIAS, and NSE. Then the selection of rainfall and temperature data according to the best bias correction method based on the results of evaluation and validation to be used as input to the AREMA model.

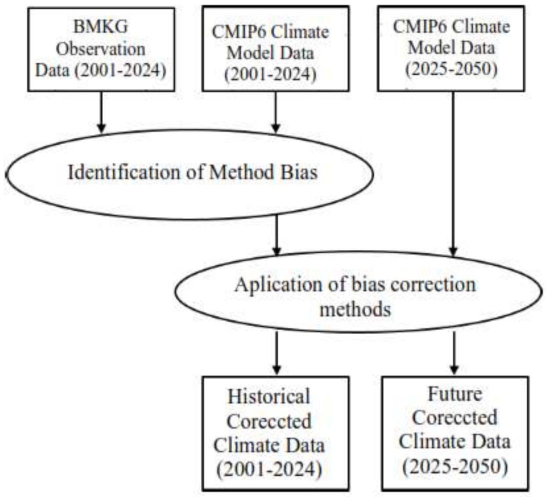

Figure 2. CMhyd model bias correction flow

ARIMA Projections

The best selection data is used as input to the ARIMA model which is processed using SPPS software to determine future temperature and rainfall trends, as well as identify climate change patterns in the Semarang City area. The data is presented in the form of a graph. Then from the results obtained, the correlation value between the prediction data and the observation data is sought for assess the degree of compatibility between the two.

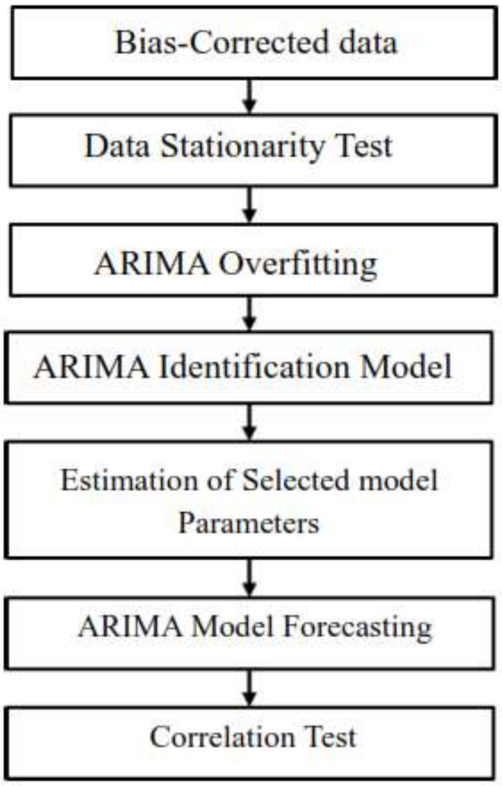

Figure 3. ARIMA Model Groove

Spatial Map Projection

Observational and future data that has been processed and correlation calculations, are projected with QGIS software. The results of the spatial map in the form of a distribution map consisting of an observation rainfall distribution map, a map of future rainfall distribution, an observation temperature distribution map and a future temperature distribution map.

III. Result and Discussion

Performance of Bias Correction Methods

Accurate climate model simulations are essential for analyzing historical climate studies and predicting future temperatures and precipitation. However, model simulation is uncertain, understanding the underlying errors and biases is important in climate research. Processing the output of climate models by eliminating bias or uncertainty, is the first step in the study of the impacts of climate change to further estimate and predict the consequences of climate change in the future. Linear scaling (LS) and distribution mapping (DM) are used to correct temperature and precipitation biases.

Table 1. Statistical indicators of bias correction for BMKG station rainfall

Station	Performance Indicators	SIM	SSP 2-4.5		SSP 5-8.5	
			LS	DM	LS	DM
Jawa Tengah	R^2	0.473	0.474	0.467	0.434	0.427
	RMSE	10.042	10.168	10.656	10.656	11.194
	NSE	0.458	0.445	0.390	0.390	0.327
	PBIAS	-14.686	-0.717	-1.748	1.178	0.363
Tanjung Emas	R^2	0.005	0.016	0.005	0.014	0.005
	RMSE	17.056	15.450	19.515	15.551	19.636
	NSE	-0.434	-0.177	-0.877	-0.192	-0.901
	PBIAS	43.557	-0.999	-2.035	0.747	0.368
Ahmad Yani	R^2	0.390	0.395	0.382	0.370	0.359
	RMSE	10.540	10.638	11.418	10.937	11.750
	NSE	0.371	0.359	0.262	0.323	0.218
	PBIAS	-6.584	0.295	-0.728	2.146	1.427

Table 2. Statistical indicator of bias correction for BMKG station maximum temperature

Station	Performance Indicators	SIM	SSP 2-4.5		SSP 5-8.5	
			LS	DM	LS	DM
Jawa Tengah	R^2	0.411	0.489	0.453	0.422	0.372
	RMSE	2.493	0.995	1.094	1.066	1.192
	NSE	-2.255	0.482	0.374	0.405	0.256
	PBIAS	-7.095	-0.243	-0.220	-0.347	-0.374
Tanjung Emas	R^2	0.070	0.357	0.263	0.334	0.233
	RMSE	3.071	1.352	1.604	1.383	1.651
	NSE	-2.566	0.308	0.028	0.277	-0.031
	PBIAS	-8.078	-0.062	-0.045	-0.165	-0.209
Ahmad Yani	R^2	0.399	0.476	0.439	0.420	0.373
	RMSE	2.905	0.980	1.083	1.039	1.161
	NSE	-3.659	0.469	0.353	0.404	0.256
	PBIAS	0.411	0.489	0.453	0.422	0.372

Table 3. Statistical indicator of bias correction for BMKG station minimum temperature

Station	Performance Indicators	SIM	SSP 2-4.5		SSP 5-8.5	
			LS	DM	LS	DM
Jawa	R^2	0.235	0.256	0.241	0.251	0.239
Tengah	RMSE	3.053	0.813	0.902	0.815	0.900
	NSE	-10.277	0.201	0.016	0.197	0.020
	PBIAS	11.714	0.073	0.094	0.015	0.014
Tanjung	R^2	0.005	0.084	0.045	0.078	0.042
Emas	RMSE	3.586	1.160	1.380	1.167	1.387
	NSE	-9.502	-0.099	-0.556	-0.112	-0.571
	PBIAS	13.621	-0.062	-0.033	-0.122	-0.124
Ahmad	R^2	0.251	0.287	0.265	0.282	0.267
Yani	RMSE	3.219	0.773	0.854	0.775	0.850
	NSE	-12.338	0.230	0.061	0.227	0.070
	PBIAS	0.235	0.256	0.241	0.251	0.239

The DM method performs better for precipitation, while the LS method performs better in terms of temperature correction. Therefore, the DM method for rainfall and the LS method for maximum and minimum temperature correction can be recommended to adjust future climate variables.

Rainfall and Temperature Validation

Model validation was carried out to evaluate the extent to which the corrected simulation data was able to represent the observation data. This validation process was carried out by comparing daily data between the results of bias correction and observation data during the period 2016 to 2024. Table 4 shows the results for R^2, RMSE, NSE, and PBIAS for simulation and observational data for precipitation, maximum temperature, and average daily minimum temperature for all three stations.

Table 4. Statistical indicators of model validation for temperature and precipitation

Station	Statistics	PCP	Tmax	Tmin
Jawa Tengah	R^2	0.002	0.136	0.033
	RMSE	19.567	1.879	1.495
	NSE	-0.347	0.997	0.996
	PBIAS	25.415	-2.609	1.703
Tanjung Emas	R^2	0.019	0.247	0.119
	RMSE	15.826	1.632	1.108
	NSE	0.065	0.998	0.998
	PBIAS	-15.347	-2.154	-0.969
Ahmad Yani	R^2	0.004	0.122	0.067
	RMSE	17.496	1.626	1.164
	NSE	-0.110	0.998	0.998
	PBIAS	14.236	-1.136	1.074

In table 4, during the validation period, rainfall shows a tendency of overestimation at Tanjung Emas Station and underestimation at Jawa Tengah Station and Ahmad Yani Station. At the same time, the model tends to overestimate Tmax at all stations, while Tmin is overestimated at Tanjung Emas Station and underestimated at Jawa Tengah Station and Ahmad Yani Station during the observation period.

Based on these results, the bias correction method used succeeded in improving the accuracy of temperature simulations, but was still less effective in improving the accuracy of daily rainfall simulations in the study area.

Future Rainfall Projection Results (ARIMA)

The projection results are illustrated in the following graph, which shows the comparison between the observation data and the ARIMA projection results from each station.

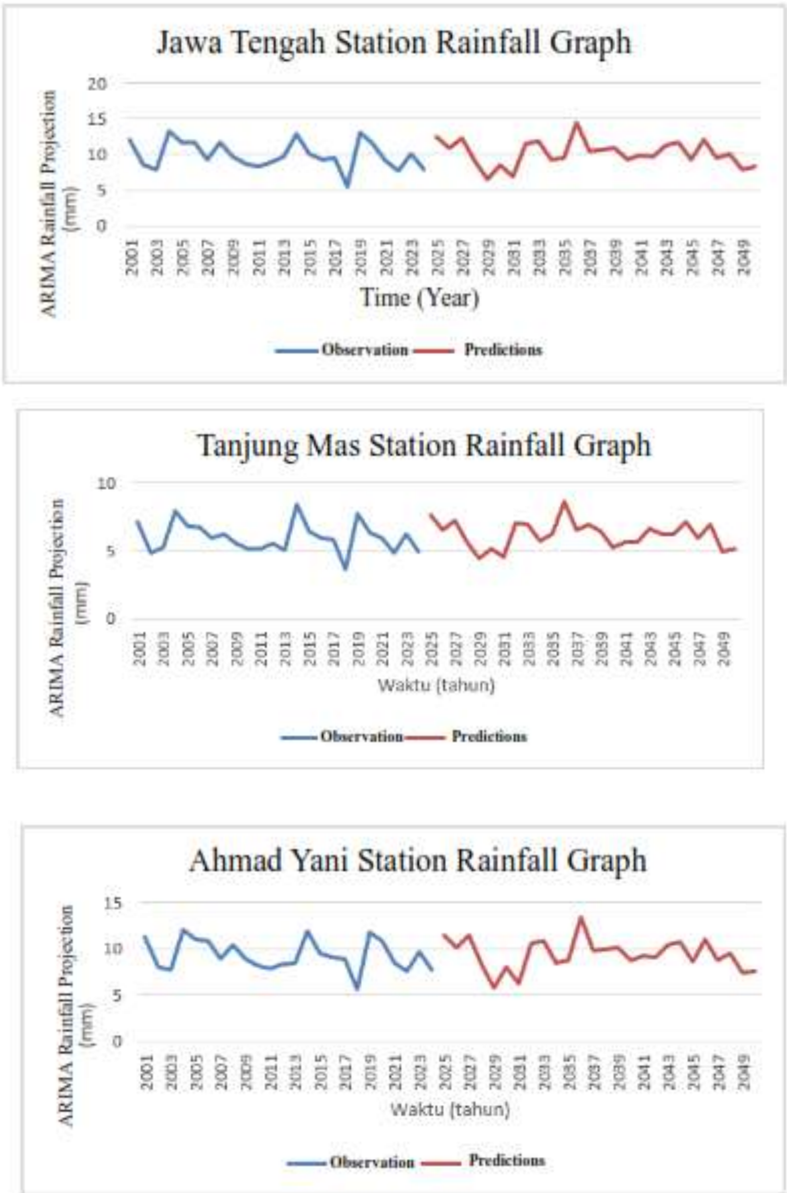

Figure 4. ARIMA projection graph of BMKG Station rainfall

Based on the three graphs and daily correlation values, it can be concluded that the ARIMA simulation model has a good performance in representing daily rainfall data, especially at Tanjung Emas Station. ARIMA's projections show a trend of increasing rainfall in all stations from 2025 to 2050, compared to 2001–2024. Although the correlation does not show a very strong relationship, the values are sufficiently supportive of the validity of the long-term projections while still taking into account the uncertainty of the local climate.

Future Temperature Projection Results (ARIMA)

Future temperature projections are important for understanding the potential for climate change at the local level, particularly in the context of rising temperature extremes or changes in daily average temperatures.

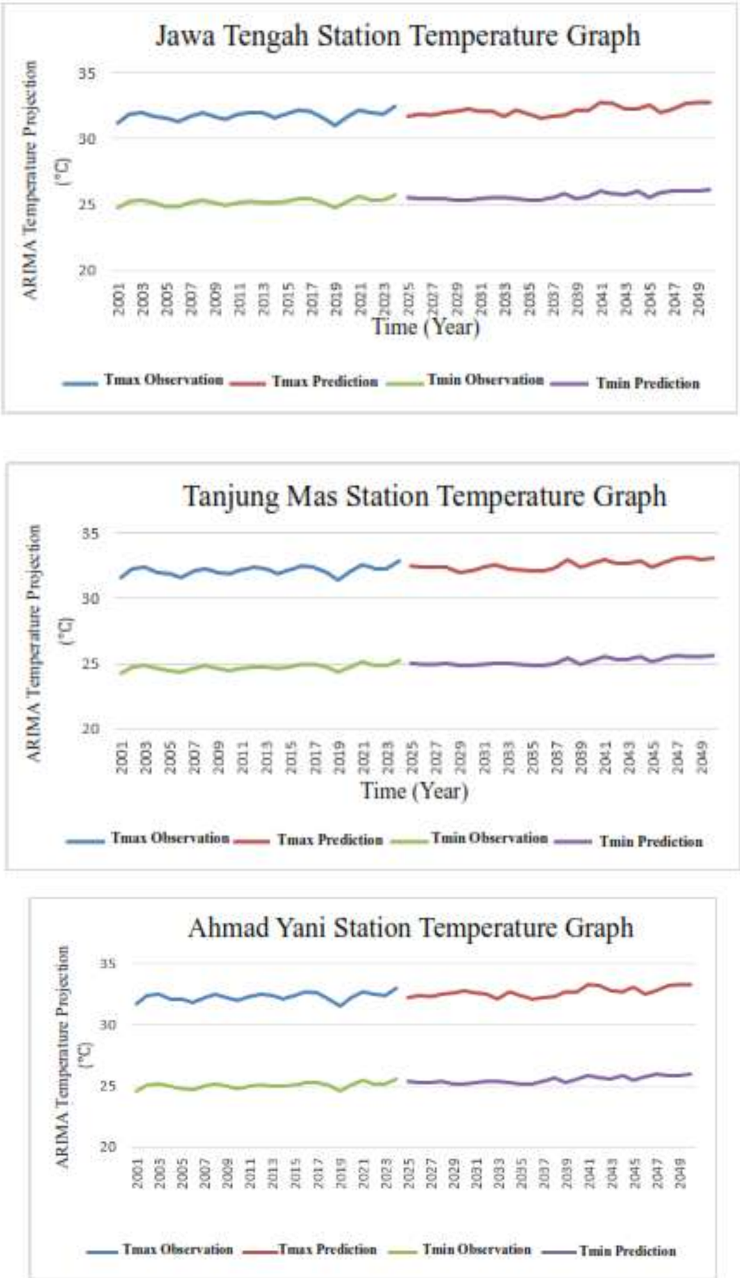

Figure 5. BMKG Station temperature projection chart ARIMA

Based on the three graphs above, it can be concluded that the ARIMA simulation model has an excellent performance in representing the daily maximum temperature at all three stations, with a correlation value above 0.897. Meanwhile, the model's performance in modeling the temperature

The daily minimum is also very good, although the correlation value is slightly lower than the maximum temperature, with a correlation value above 0.839. ARIMA's projections show a trend of rising air temperatures across stations until 2050. However, overall, these results show that the model is quite accurate and reliable in capturing daily temperature patterns, both for maximum and minimum temperatures, making it feasible to use in long-term temperature projection studies in the Semarang area and its surroundings.

Rainfall Distribution Map

The distribution map in figure 6 and figure 7 shows the spatial distribution of rainfall in the Semarang City area. In the context of this study, the analysis of rainfall distribution is an important step to understand the differences in conditions between regions and their relation to climate dynamics in Semarang City.

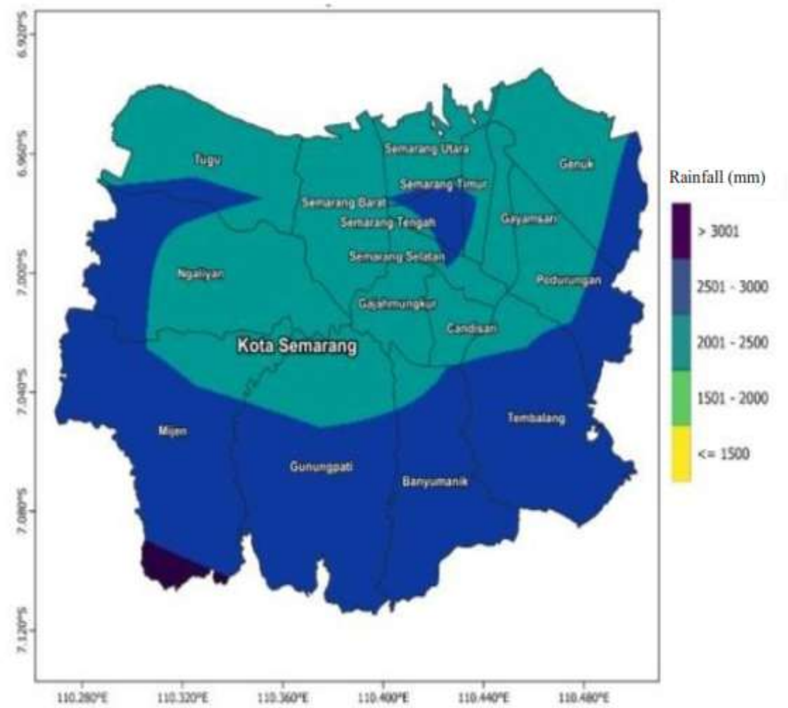

Figure 6. Map of rainfall distribution in 2001-2024

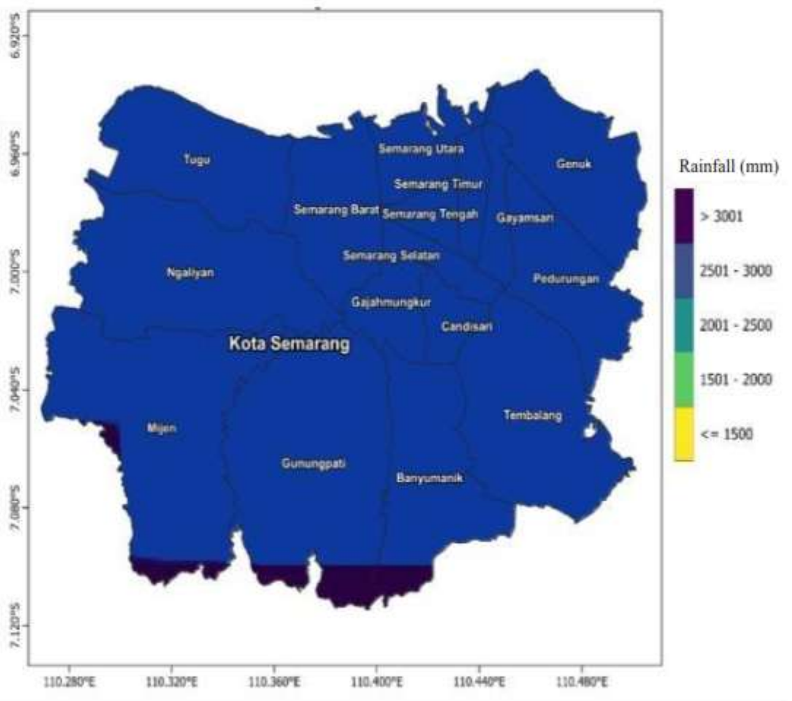

Figure 7. Map of rainfall distribution in 2025-2050

Based on figure 6 and figure 7, if compared, it can be said that Semarang City will experience an increase in rainfall in the future where on average from the amount of annual rainfall in 2001 to 2024, Semarang City is in the very wet, wet and humid class. Meanwhile, in 2025 to 2050, the rainfall received is relatively wetter, as evidenced by the absence of a humid class and only a very wet and wet class. Based on the results obtained, the rainfall trend in 2025–2050 has increased by 159 mm – 240 mm per year compared to 2001–2024. The results of the study [8], rainfall in Semarang City has increased steadily.

Temperature Distribution Map

The distribution map in figure 8 and figure 9 shows the spatial distribution of air temperature in the Semarang City area.

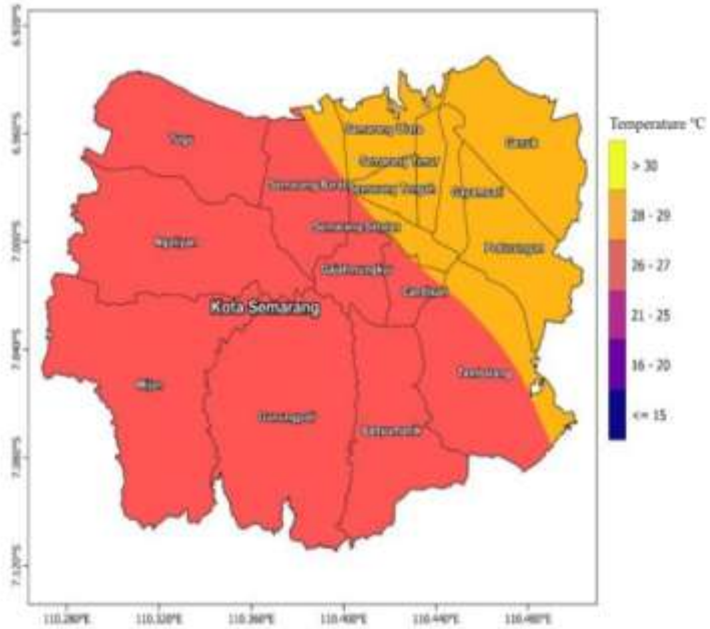

Figure 8. Map of air temperature distribution in 2001-2024

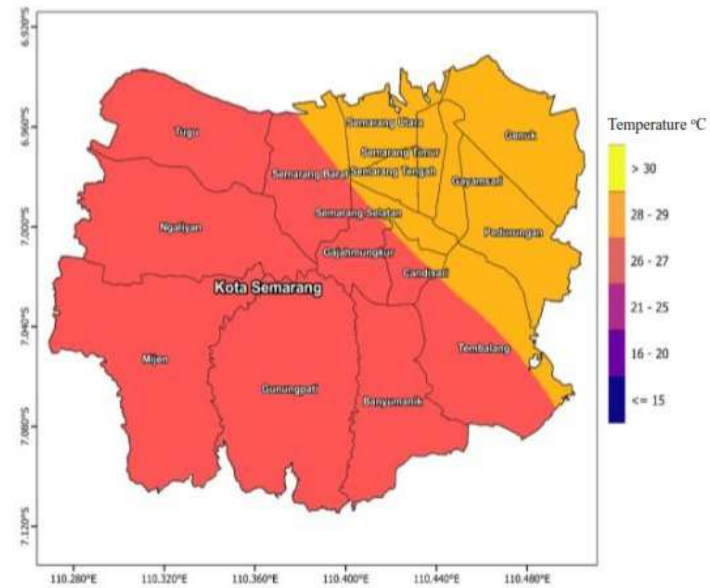

Figure 9. Temperature distribution map in 2025-2050

Based on figure 8 and figure 9, if compared, it can be said that the city of Semarang will also experience an increase in air temperature in the future where on average the amount of annual rainfall in year 2001 until 2024, The city of Semarang is in the hot and hot class. Meanwhile, from 2025 to 2050, air temperatures will still fall into the same category, namely warm and hot.

The projected temperature in Semarang City in the future period has increased compared to the past period [3], this is in line with the results of this study, where the average temperature for the period 2025-2050 increased by 0.03°C – 0.1°C compared to the temperature in the period 2001–2024. This increase in temperature is in line with the trend of global warming where urban areas in tropical countries including Indonesia are estimated to experience a temperature increase of around 0.8°C/100 years [3].

This condition is closely related to the phenomenon of Urban Heat Island (UHI), where densely populated areas and industrial areas tend to store heat for longer due to the dominance of heat-absorbing materials such as asphalt and concrete, as well as the lack of vegetation cover [9]. This projection is important as an indication that climate change is not only having a global impact, but is real and measurable on an urban scale such as in the city of Semarang.

IV. Conclusion

1. The air temperature projection yields the daily correlation values of BMKG Jawa Tengah Station for Tmax 0.901 and Tmin0.839. Tanjung Emas BMKG Station has a daily correlation value of Tmax of 0.938 and Tmin of 0.877. BMKG Ahmad Yani Station for Tmax is 0.897 and Tmin is 0.842. The ARIMA model has a tendency to increase in temperature in the future.
2. The map of the distribution of annual rainfall in Semarang City in 2025–2050 is in the very wet and wet class. Meanwhile, the map of the distribution of annual air temperature in Semarang City in 2025–2050 is in the warm and hot classes.

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