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Prediction of Future Rainfall using SDSM at Bukit Merah Catchment

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Abstract: From decades to millennia, climate change is a shift in the statistical distribution of weather patterns. Climate change may alter the mean weather conditions, as well as the frequency and duration of weather fluctuations, more or fewer extreme weather conditions such as floods and droughts. Climate change directly affects natural resource depletion, infrastructure, the environment, and human health. Also, certain indirect consequences may be severe. The primary goal is to investigate and establish the use of the Statistical DownScaling Model (SDSM) in predicting the future and precipitation of a specific catchment area in peninsular Malaysia by downscaling the current climate change from 2010 to 2021 and future climate variables for the Bukit Merah basin, and also to predict the rainfall impact of climate change on the Bukit Merah reservoir from 2022 to 2050. Bukit Merah watershed has its own reservoir (BMR). It is also known as Bukit Merah Lake. Freshwater lakes and reservoirs provide water for home use, irrigation, agriculture, and industry. Thus, this study has used statistical downscaling to predict future rainfall in the catchment Bukit Merah by Statistical Downscaling Method (SDSM). From this study, the outcome result of R2 and RSME of selected rainfall stations showed that mostly the values of R2 were lower but the values of RSME were higher which caused in poor performance of the statistical method. Besides, RCP 4.5 and RCP 8.5 scenarios indicated Bukit Larut has the highest mean rainfall values which were 22.63 mm and 23.52 mm while Bukit Merah has the lowest mean rainfall values which were 3.76 mm and 1.24 mm in 30 years later.

Keywords: Climate change, SDSM, Bukit Merah, Floods, Drought, Rainfall

1. Introduction

Since the Industrial Revolution, human activities have been cited as major contributors to climate change and global warming, notably the burning of fossil fuels for electricity and heating, agricultural operations, deforestation, and land use changes, Cartesian & Chameids The United Nations Framework Convention on Climate Change (UNFCCC) defines climatic change as a change in the composition of

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the global atmosphere caused by human activities, as opposed to natural climate variability. The combustion of fossil fuels and changes in land cover and land use are suspected of contributing to the increase in atmospheric greenhouse gas concentrations [1]. Their effects have been detected throughout the climate system, and they are very likely to be the major cause of the observed warming since the mid-20th century. Several secondary repercussions are also predicted to be negative

From this research, it has examined how to apply the Statistical DownScaling Method to forecast future rainfall amounts. As a result, this study will rely on the output of climate models. Additionally, statistical indicators will be employed to determine the effect of climate change on rainfall. The research concentrated on the Bukit Merah catchment region in Malaysia's Perak state. SDSM is a technology that helps individuals make judgments by lowering the geographic size of data from a large-scale General Circulation Model (GCMs). The most feasible models are employed to simulate Bukit Merah's temperature data. SDSM also contains data for downscaling when using current climate predictions.

2. Materials and Methods

2.1 Study Area

The study area is in Bukit Merah, Perak. Malaysia. Bukit Merah Reservoir's (BMR) catchment zone is located at latitude 100° 39' 14 7" E and longitude 5o 01' 06 8" N. BMR is Malaysia's first man-made lake, measuring 13.88 kilometres north to south and 4.5 kilometres east to west. The Bukit Merah Dam is comprised of a main structure, two saddle structures, an operating spillway with gate, an auxiliary spillway with gate, and an irrigation intake. BMR's principal aims were to provide irrigation water for double cropping on 24000 hectares of paddy land in the Kerian area, as well as to offer residential and industrial water to Kerian and Larut Matang inhabitants. In BMR, the most significant land uses are virgin and primary forest (46.29 percent), agricultural (palm oil plantation), and commercial breeding farming (national Boer breeding facility) (42.80 percent)[2].

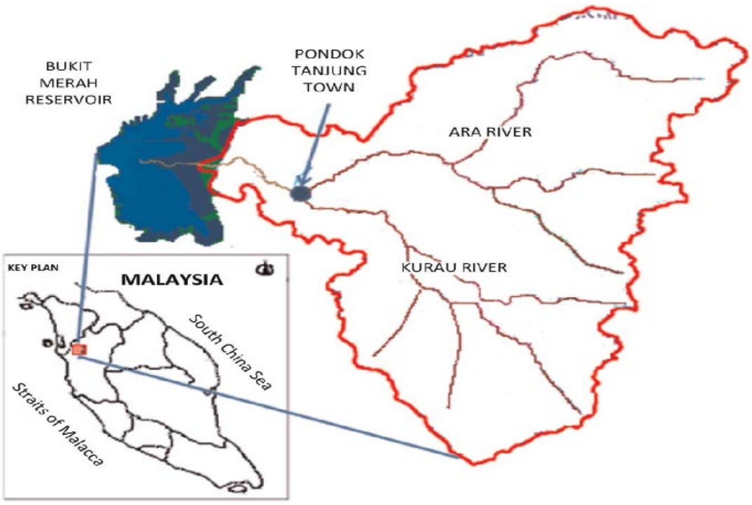

Figure 1: Location of Bukit Merah Reservoir (BMR)

2.2 Data Collection

Precipitation data

Precipitation data is the most important input for the calibration and simulation of the weather generator model, and it is also the most easily accessible. In this work, the precipitation time series data from 2010 to 2021 were utilised to produce statistical indices, which were then used to select representative observation stations for downscaling and calibration of the large-scale predictors using the Global Circulation Model (GCM).

Table 1: Selected rainfall stations of Bukit Merah Reservoir (BMR)

No. of station	Name of station	Latitude	Longitude
4807016	Bukit Larut, Taiping	04° 51’ 45”	100° 43’ 35”
4908018	Pusat kesihatan kecil (Batu 14), Batu Kurau	04° 58’ 4”	100° 48’ 15”
5006021	Kolam Air Merah (Bukit Merah Reservoir)	05° 02’ 00”	100° 39’ 10”

2.3 Statistical Downscaling Model (SDSM) Software

Because of the poor geographical resolution of the output from General Circulation Models (GCMs), the output from rainfall projection effect studies is difficult to employ in these investigations. As a result, downscaling approaches, specifically the statistical downscaling method, were employed. When it comes to understanding the local atmosphere and atmospheric properties, this program relies on a simplified mathematical equation to do so. Furthermore, the model does not need a large amount of processing power in order to display the results of the simulation, and the data is provided at finer resolutions that are more focused on the research region than previously. As a result of climate change, the statistical downscaling approach will be utilized to create the rainfall trend for Bukit Merah during the past 29 years.

During this investigation, SDSM software version 4.2.9 was employed. Several additional climate studies in Malaysia's region have made use of this version, which includes the most relevant predictors and predictands for the situation.

2.4 Relative Error and Root Mean Square Error (RMSE)

For the purpose of comparing the form of observed and prospective rainfall data, the differences between the desired output and predicted output are combined and compared with the relative error (*RE*) and root mean square error (RMSE). The root mean squared error is abbreviated as RMSE. It is based on the premise that data errors are distributed normally. This is a metric for the average difference between model predictions and the dataset's actual values. R2 is the coefficient of determination, which is scaled from 0 to 1. The approaches employed in this study are as follows:

Relative Error (RE):

$$\text{RE: } \frac{Past - Future}{Past} \quad Eq. 1$$

The Root Mean Square Error (RMSE) was employed for the spatial time series analysis in this study.

Root Mean Square Error (RMSE):

$$\text{(RMSE): } \frac{1}{n}\sum_{i=1}^{n}[Q_p\ (i) - Q_f\ (\text{i})] \quad Eq. 2$$

3. Results and Discussion

3.1 Calibration and Validation of Rainfall Data

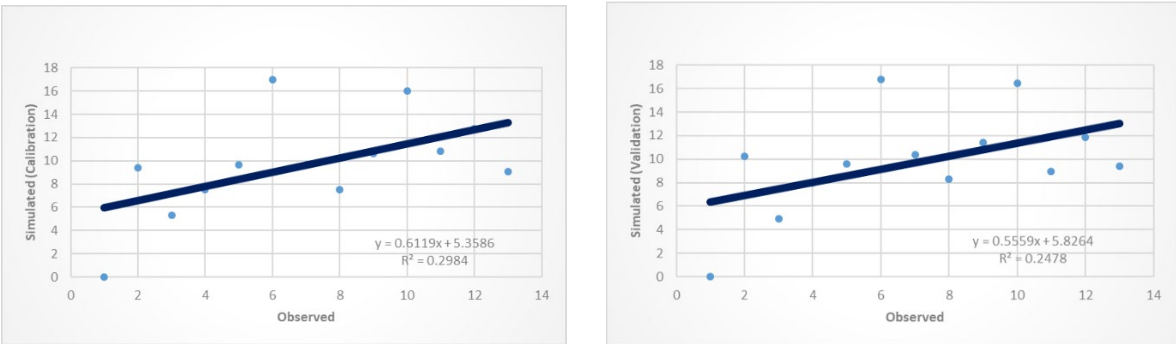

Figure 2: Results of mean (mm) of future rainfall of calibration and validation at Bukit Larut

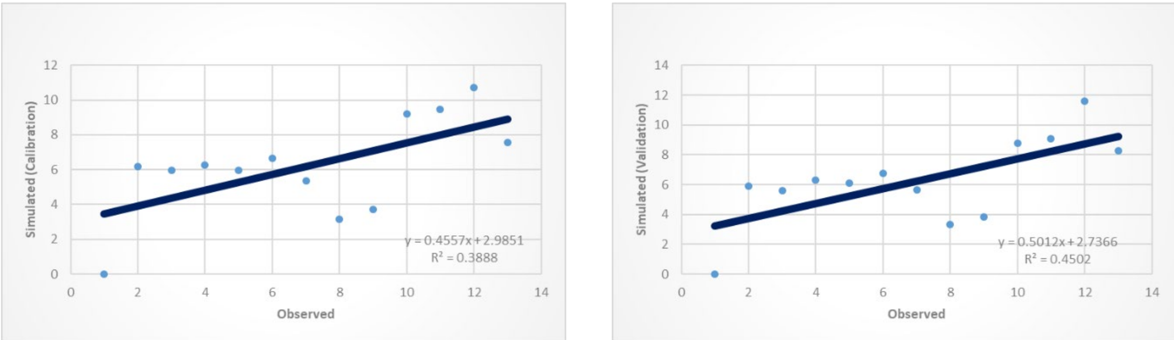

Figure 3: Results of mean (mm) of future rainfall of calibration and validation at Bukit Merah

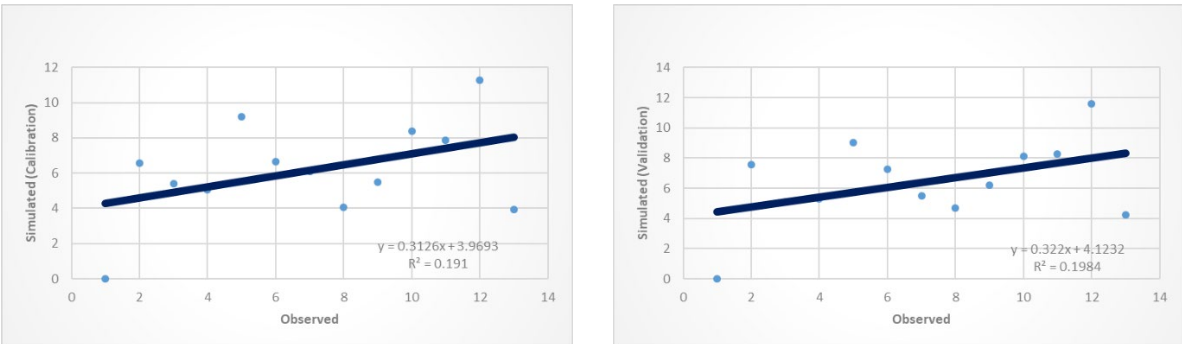

Figure 4: Results of mean (mm) of future rainfall of calibration and validation at Pusat Kesihatan Kecil

Table 2: The R2 and RMSE between observed and simulated rainfall results for each station for the SDSM model

	R^2		RMSE	
Station name	Calibration	Validation	Calibration	Validation
Bukit Larut, Taiping	0.30	0.25	3.08	2.82
Kolam Air, Bukit Merah	0.89	0.45	2.09	4.20
Pusat Kesihatan Kecil, Batu Kurau	0.20	0.20	1.65	1.75

As shown in Table 2, Bukit Merah station has a higher R2 than other stations during calibration, with a value of 0.89. Bukit Merah Station also has the highest R2 value of 0.45 among all stations for validation. During calibration, Bukit Larut Station had the greatest RMSE of 3.08 mm/day, while Bukit Merah Station had the highest RMSE of 4.20 mm/day. The NCEP daily rainfall series has a mean R2 of above 0.3, which is close to literature values. For example, Bukit Larut Station, the calibrated value is 0.3, while the validation value is 0.25. Due to the huge number of relative errors present in the calibration process, the R2 was bigger in the calibration phase than in the validation phase. Aside from that, the calibration phase RMSE was higher than the validation phase.

RMSE values between 0.2 and 0.5 indicate that the model can reasonably predict the data properly. Furthermore, Adjusted R2 greater than 0.75 is an excellent figure for demonstrating accuracy or it was better if the R2 value can reach 1. Adjusted R2 of 0.4 or greater is acceptable in some instances. From the summary of R2 and RMSE results of the study, the R2 values were not achieve 0.4 or greater than 0.75, which far from 1 except the Bukit Merah Station, which indicated 0.89 in calibration and 0.45 in validation of R2 but the RSME values was greater and exceeded 0.5 which was same with another rainfall stations. To get good results with the Statistical Downscaling Method (SDSM), a low value of RMSE are required [4].

Following the findings of Hamidon et al. (2016), who conducted a research study on Prediction of Future Climate Change for Rainfall in the Upper Kurau River basin, Perak using Statistical Downscaling Model (SDSM), the results were similar to those of this study, with the exception that the value of R2 for rainfall stations was lower, while the result of RMSE was higher. The results of the investigation revealed that the SDSM model performed poorly in forecasting daily rainfall when compared to actual and simulated rainfall [4].

3.2 RCP 4.5 of Prediction Future Rainfall

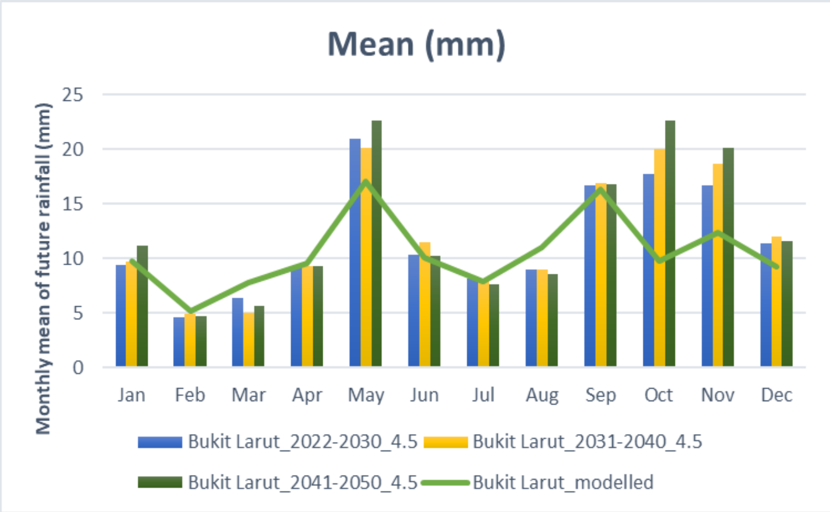

Figure 5: Results of the mean (mm) of future rainfall for RCP 4.5 at Bukit Larut

Bukit Larut Station, the forecast mean (mm) precipitation for Bukit Larut is 4.61 mm, which is lower than the 5.19 mm predicted by the model. It occurred in the 2030s, which corresponds to February. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. The drought calamity may strike in the 2030s during February, as it was the driest month in comparison to the 2040s and 2050s. Additionally, May had the greatest mean (mm) of anticipated precipitation with a value of 22.63 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation. In the 2050s, the flood disaster may occur in May, as it was the wettest month in comparison to the 2030s and 2040s.

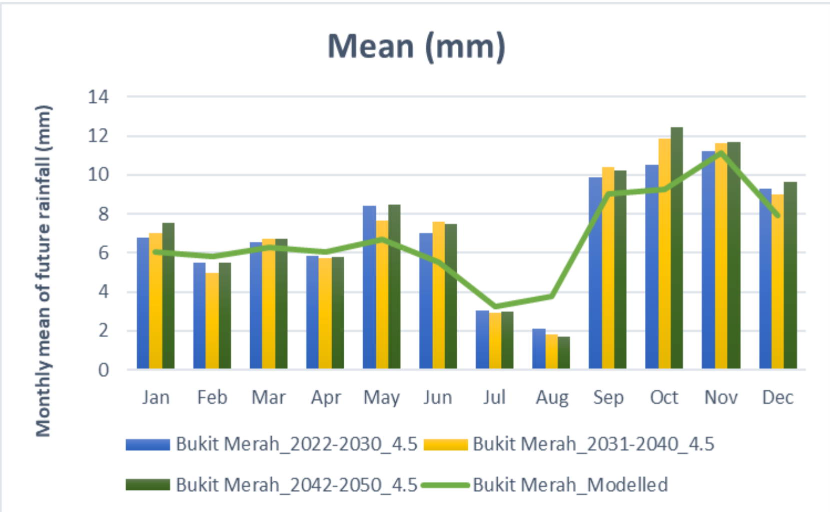

Figure 6: Results of the mean (mm) of future rainfall for RCP 4.5 at Bukit Merah

Apart from that, Bukit Merah Station's projected mean (mm) precipitation is 1.67 mm, which is lower than the 3.76 mm predicted by the model. It occurred in the 2050s, which corresponds to August. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. August in the 2050s may be the year of the drought calamity, as it was the driest month in comparison to the 2030s and 2040s. Additionally, October had the greatest mean (mm) of anticipated precipitation with a value of 12.42 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation.

In the 2050s, the flood disaster may occur in October, as it was the wettest month in comparison to the 2030s and 2040s.

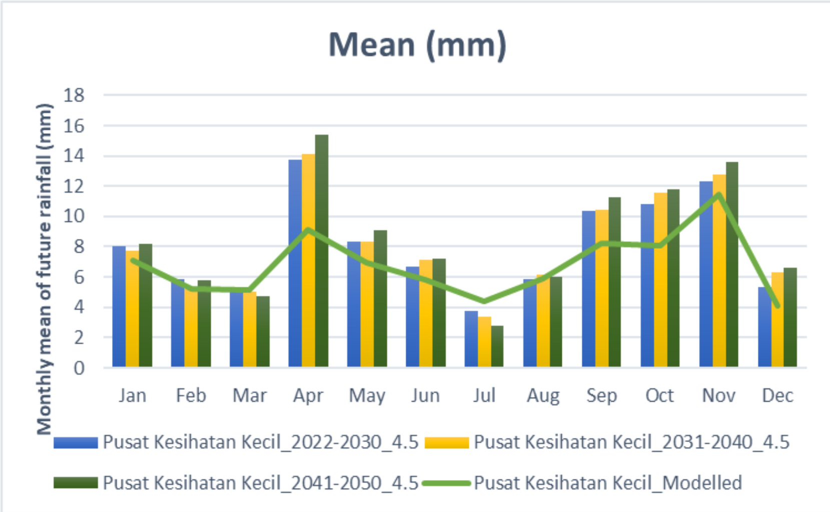

Figure 7: Results of the mean (mm) of future rainfall for RCP 4.5 at Pusat Kesihatan Kecil

Pusat Kesihatan Kecil Station's lowest future mean (mm) precipitation is 2.81 mm, compared to 4.37 mm in the simulated data. It occurred in the 2050s, which corresponds to July. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. July 2050 may be the year of the drought calamity, as it was the driest month in comparison to the 2030s and 2040s. Additionally, the highest mean (mm) of predicted precipitation occurred in April, at 15.42 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation. In the 2050s, the flood disaster may occur in October, as it was the wettest month in comparison to the 2030s and 2040s.

3.3 RCP 8.5 of Prediction Future Rainfall

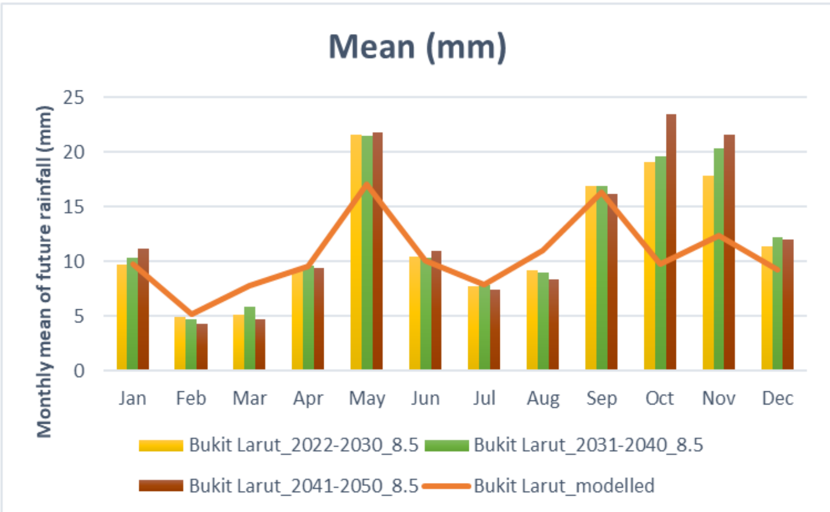

Figure 8: Results of the mean (mm) of future rainfall for RCP 8.5 at Bukit Larut

Bukit Merah with data from a model. Bukit Larut Station's lowest future mean (mm) precipitation is 2.5 mm, compared to the 5.19 mm predicted by the model. It occurred in the 2050s, which corresponds to February. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. The drought calamity may strike in the 2050s during February, as it was the driest month in comparison to the 2030s and 2040s. Additionally, May had the greatest mean (mm) of anticipated precipitation with a value of 23.52 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation. In the 2050s, the flood disaster may occur in October, as it was the wettest month in comparison to the 2030s and 2040s.

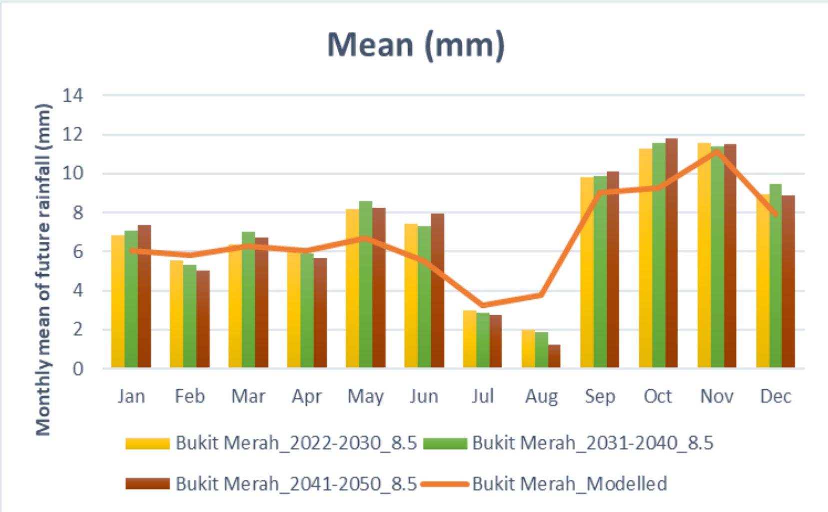

Figure 9: Results of the mean (mm) of future rainfall for RCP 8.5 at Bukit Merah

Following that, Bukit Merah Station has the lowest projected mean (mm) precipitation of 1.24 mm, compared to the 3.76 mm predicted by the model. It occurred in the 2050s, which corresponds to August. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. August in the 2050s may be the year of the drought calamity, since it was the driest month in comparison to the 2030s and 2050s. Additionally, October had the greatest mean (mm) of anticipated precipitation with a value of 11.82 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation. In the 2050s, the flood disaster may occur in October, as it was the wettest month in comparison to the 2030s and 2040s.

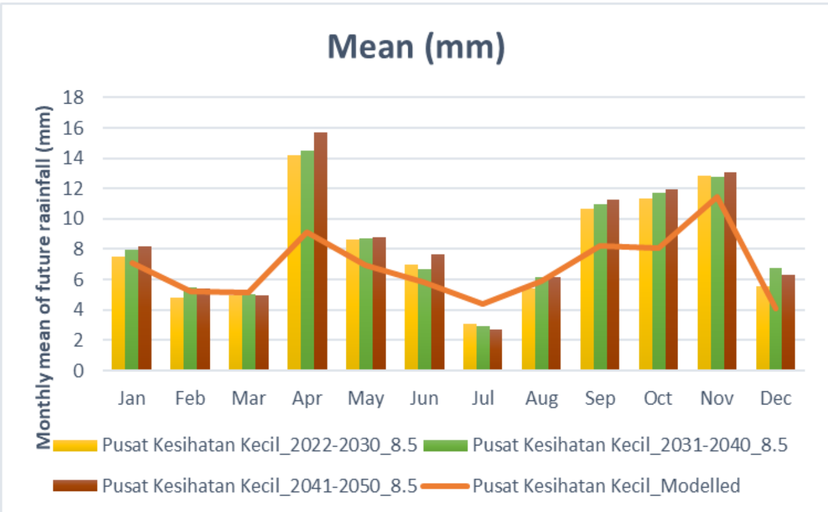

Figure 10: Results of the mean (mm) of future rainfall for RCP 8.5 at Pusat Kesihatan Kecil

Pusat Kesihatan Kecil Station's lowest future mean (mm) precipitation is 2.71 mm, compared to 4.37 mm in the simulated data. It occurred in the 2050s, which corresponds to July. Climate change would occur at the lowest mean (mm) precipitation value owing to the lack of precipitation. July 2050 may be the year of the drought calamity, as it was the driest month in comparison to the 2030s and

2040s. Additionally, the highest mean (mm) of predicted precipitation occurred in April, at 15.72 mm. It was the greatest mean (mm) precipitation value observed in comparison to the modelled data. The 2050s would see the highest mean (mm) of future precipitation. In the 2050s, the flood disaster may occur in October, as it was the wettest month in comparison to the 2030s and 2040s.

3.4 Discussion on RCP 4.5 and RCP 8.5 Scenarios

Based on the results of this study's RCP 4.5 and RCP 8.5 simulations, the mean monthly rainfall for the future among the three locations is generally increasing. Bukit Larut Station has the highest change in rainfall between 2030 and 2050. When historical rainfall is examined, the Bukit Merah Station has the least change in rainfall in the 2030s, 2040s, and 2050. The outcome results through the graph patterns between forecast and observed rainfall values at three locations which were Bukit Larut, Bukit Merah and Pusat Kesihatan Kecil shown that the Bukit Merah catchment will see more rainfall in the future.

For example, during a drought, a lack of rainfall is frequently followed by a rise in temperature. It is still controversial whether the increasing temperature is a consequence of the drought or a cause of the drought. Regardless, research indicates that drought impacts are associated with increased temperature in Australia and elsewhere. Even if the temperature increase associated with rainfall insufficiency is small and not necessarily severe, it may raise risks and repercussions. Thus, tracking the history of composite occurrences including low rainfall and high temperatures may be beneficial for risk management, especially in light of human-induced global warming. Researchers have examined the spatial distribution of precipitation in a variety of ways, and a wealth of information about the mechanisms underlying the distribution has been published in which are used in studies of climate, urban planning, flood disasters caused by heavy rain, and a variety of other water-related issues [5].

According to Hamidon et al.'s study, the result was also similar to this study, with Bukit Larut becoming the highest station in mean (mm) rainfall changes in the 2030s, 2040s, and 2050s, followed by Bukit Merah Station and Pusat Kesihatan Kecil. Even though the previous study used ten rainfall stations, it also included Bukit Larut, Bukit Merah, and Pusat kesihatan Kecil.

4. Conclusion

To summarise, the SDSM model accurately predicted future rainfall in the Bukit Merah basin, suggesting its potential. From the summary of R2 and RMSE results of the study, the R2 values were not achieve 0.4 or greater than 0.75, which far from 1 except the Bukit Merah Station, which indicated 0.89 in calibration and 0.45 in validation of R2 but the RSME values was greater and exceeded 0.5 which was same with another rainfall stations. To get good results with the Statistical Downscaling Method (SDSM), a low value of RMSE are required. For the results of RCP 4.5 and RCP 8.5, Bukit Larut Station is wetter than Bukit Merah and Pusat Kesihatan Kecil, hence the daily and monthly rainfall downscaled at Bukit Larut Station has more fluctuation over the validation period. Because of this, the model underestimated rainfall in Bukit Larut, especially in the 2050s.

For recommendation, flooding occurs frequently in Malaysia, affecting almost a fifth of the country. Pluvial flooding occurs when precipitation runs off the surface and pools in temporary ponds in depressions due to inadequate conveyance capacity for the intensity of the rainfall according to Houston, flooding is a broad term that refers to any place submerged underwater (2011). Improved sewage systems help lessen flood damage. The Malaysian Sewage Industry Guidelines (MSIG) use flow design parameters from the Malaysian Standard Code of Practice for Design and Installation of Sewerage Systems. Sewage pipes can also be rebuilt if needed. To keep up with the weather, Goh Shing Yi recommends citizens listen to the radio, watch the TV, or visit the meteorological department's website.

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