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Prediction of Future Temperature and Rainfall Characteristics Using Statistical Downscaling Model (SDSM) for Ibu Bekalan Jelai Station in Kurau River Basin

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Abstract: Bukit Merah is the centre of tourism (Bukit Merah Laketown Resort) and farming (paddy irrigation). Nevertheless, climate change affects this region as it is affected by low dry seasonal water levels and high quantities of monsoon water causing floods. This work discusses the use of Statistical Downscaling Model (SDSM) in the Bukit Merah. Projection using the Statistical Downscaling Model (SDSM) to obtain detailed data on expected rainfall and temperature in the Bukit Merah. Using this model as a tool to forecast something that could boost the economy of the tourism sector at Bukit Merah Laketown Resort, Perak in the Bukit Merah area. As a result of this survey tourists are anticipating the optimal time to come to Bukit Merah based on the weather prediction. The research starts with the compilation of data from the departments concerned and proceeds to calibrate and verify the data. These data must be measured and checked properly since the validation of the data will affect all outputs and outputs. To complete this stage, continue to forecast future precipitation depends on the goals of the investigation. In this analysis, we forecast future rainfall and temperature in 2020 to 2050. As a result, potential rainfall is the minimum and maximum temperature for 2020 to 2050. The outcome is a positive result for potential tourism and agriculture in the bukit merah.

Keywords: Rainfall, SDSM, Floods, Statistical Modelling, Future Rainfall Data, Reservoir

1. Introduction

Reducing freshwater supplies and growing demand for industry and agriculture are critical for the efficient management of freshwater resources. Recently, water shortage conditions in the world have

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changed from relative abundance to scarcity. Over the years, population growth and urbanization are continuously rising stresses and constraints on water sources, resulting in growing demand for water [1]. It includes some of the places where water sources are disrupted, as is the case in Selangor. As river flows dried up, water levels plunged to critical levels in seven state dams, including as low as 31 per cent of the capacity of the Sungai Selangor Dam, which supplies more than 60 per cent of state water. This incredibly low reserve level triggered water rationing, which affected more than 6.7 million people and lasted between March and May 2015. [2]. As a result of reduced access to commercial water, at least 30 state-owned firms have suffered losses of more than MYR 1 million, especially in the food and beverage, rubber, pharmaceutical, electrical and tourism industries. Apart from that, food production accounts for 85 per cent of water consumption worldwide and is expected to grow by 2050. [3].

The research site, Bukit Merah Reservoir, is located in the state of Perak and has been established as the primary water reservoir of the Kerian Irrigation Scheme, the Kerian District and the Larut Matang Region. The reservoir's primary objective is to provide double-cropping irrigation soil to nearly 24,000 hectares of paddy land beneath the Kerian River. The Kerian Irrigation Scheme has difficulties in sustaining irrigation water supply due to climate change, and the water needs for paddy irrigation require varying water supply due to spatial and temporal variations [4].

1.1 Objectives and scopes

The objectives of this study are to calibrate and validate temperature simulation for selected river basin using SDSM model. By using data from department of meteorology, calibrating and validating process can be conducted easily with the right procedure. In addition, this study also need to calibrate and validate rainfall simulation for selected river basin using SDSM model. Rainfall catchment rate data obtained from drainage and irrigation department will be used to calibrate and validate to get ready-data before proceed to forecasting future rainfall and temperature. Last but not least this study are to predict the temperature and rainfall for selected river basin from year 2020 until 2050. This prediction will improve the preparation for future natural phenomenon of study area.

The predictive statistic downscaling model (SDSM) is the research tool used in this analysis. The statistical downscaling model uses Ipoh temperature data provided by The Malaysian Meteorological Department (MMD) and the Department of Irrigation and Drainage (DID) have created the Ibu Bekalan Jelai Station. The details would be downscale to predict temperature future and rainfall of Bukit Merah reservoir. Both details must be analyzed in time intervals and estimated. Past data obtained in the 2010–2020 period. The place of the study that was chosen is Ibu Bekalan Jelai Station in Kurau River Basin, Ipoh, Perak. This research involves the use of Statistical Downscaling Model (SDSM Model) for predict the future rainfall and temperature data for the river. The data obtained will be observed to ensure that if any bad natural phenomenon happen for the future.

1.2 Background of study area

The project is in Ibu Bekalan Jelai, Kurau River Basin in Perak as shown in Figure 1. The latitude and longitude of Ibu Bekalan Jelai are 5°00’45”N 100°43’55”E respectively and located 17.9 km from Taiping, Perak. There are one main rivers which near to Kurau river Basin, which is Jelai River. As shown in figure 2, the nearest village around that area is Kampung Hangus and Kampung Jelai which is most of the population is malay. The size of the basin consists of 322 km2 was originally designated by the Federal and State government as a site area to cater to the water supply in Perak especially for Kuala Kurau, Bukit Merah, Bagan Serai and Taiping district. Based on research, the Department of Irrigation and Drainage provide 5 station to obtained rainfall data in Kurau river Basin. The 24-hour average temperature is 32.0° C at maximum temperature and 24.0° C at minimum temperature. The key land use in the study area consists of the built-up area, village, highway, farm, grassland, woodland and aquaculture.

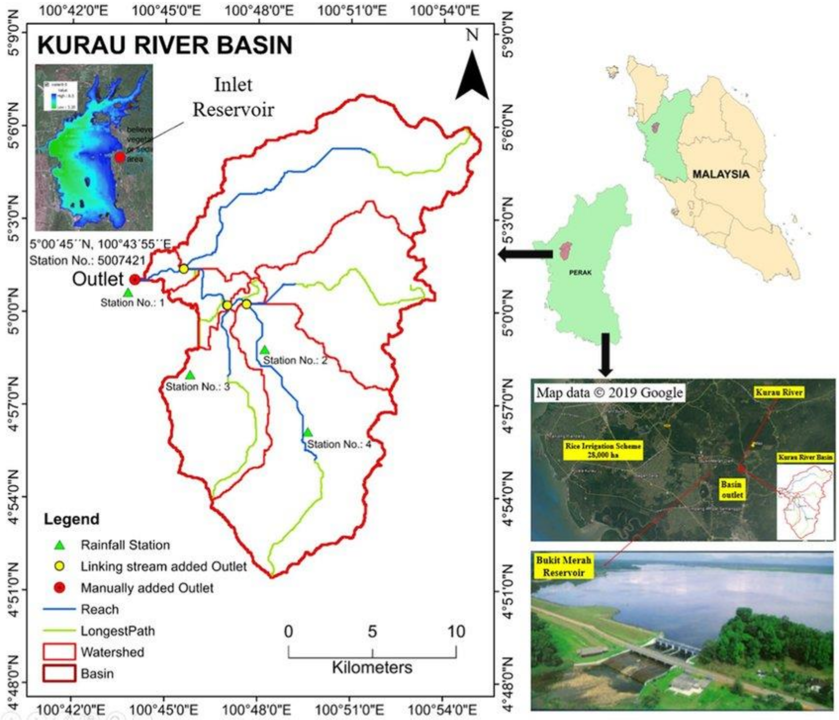

Figure 1: Area of Kurau River Basin

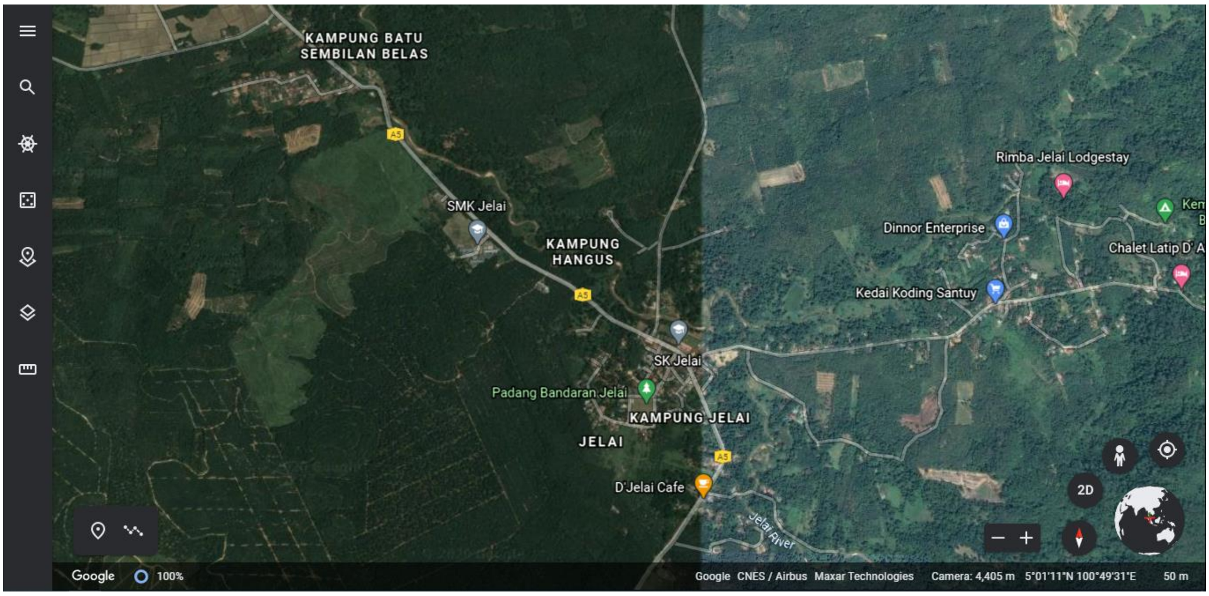

Figure 2: Location of the study area

2. Materials and Methods

2.1 Software involve

In this Project area, the applications that we used is Statistical Downscaling Model (SDSM) for calibrating and validating data that get from Department of Irrigation and Drainage Ampang, and malaysian meteorological department for selected study area. SDSM is a user-friendly software program designed to apply mathematical downscaling methods to obtain high-resolution monthly climate details from coarse-resolution climate model (GCM) simulations. The program also uses the methods of the weather generator to generate several realizations (sets) of synthetic regular weather sequences. These criteria are met with all types of area for which there is an interest in the study of the weather forecasting and future data prediction. SDSM can be used although impact analyses include small-scale climate scenarios, given quality observational data and regular GCM production for large-scale climate variables are available. The production of this program would include site-specific daily scenarios for maximum and minimum temperatures, precipitation, humidity depending on the settings we set. SDSM also produces a variety of statistical factors, such as variances, extreme frequencies, spell lengths. The flow map is very helpful to illustrate the sequence of acts to complete the project as seen in Figure 3.

2.2 Methods

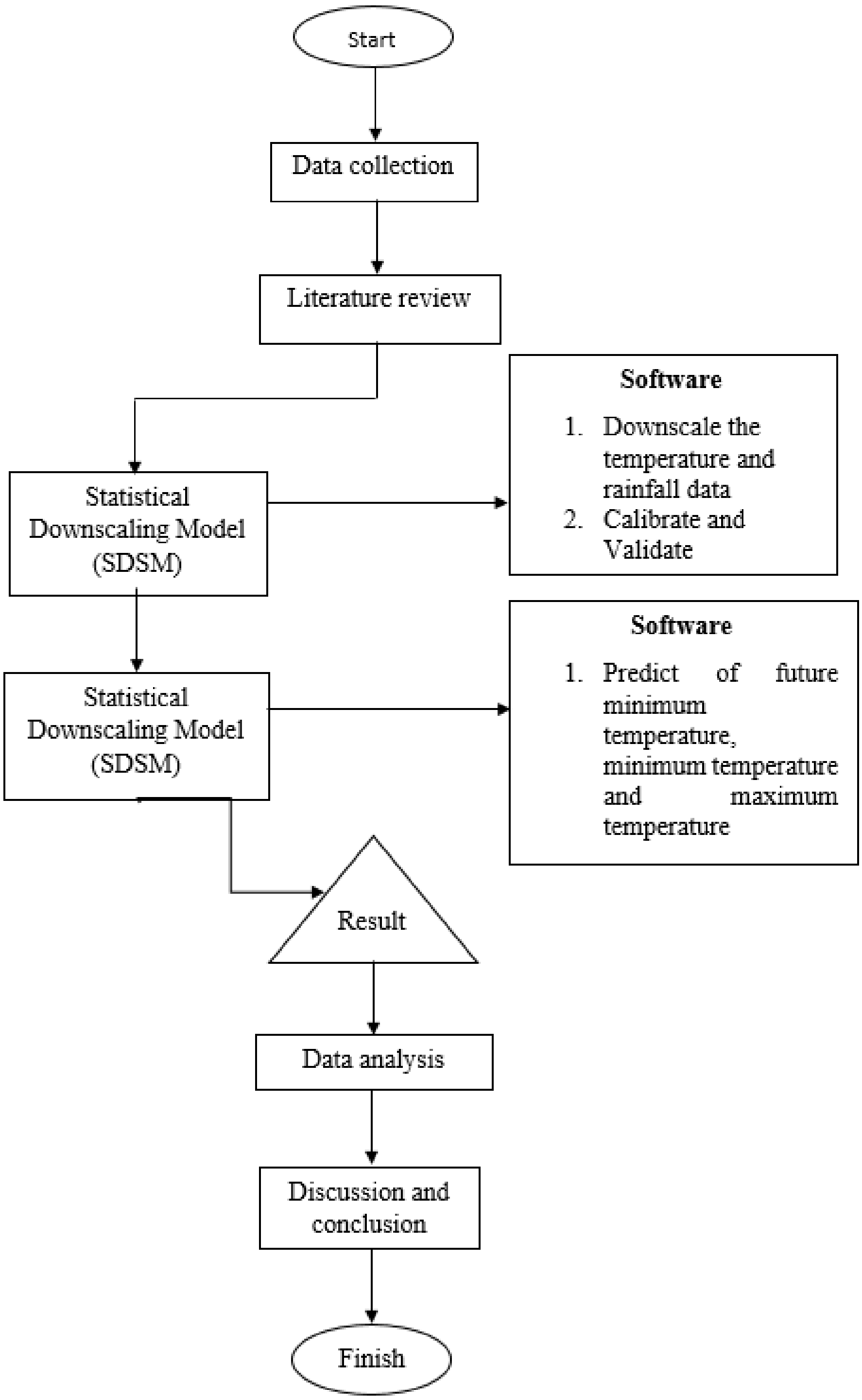

Figure 3: The flowchart of the methodology of this project

2.3 Methodology

In this analysis, the statistical downscaling model (SDSM) will be used to produce daily precipitation and temperature at the Bukit Merah reservoir as feedback for the hydrological model. SDSM is a combination of a stochastic weather generator and a multilinear regression that causes synoptic weather variables to use statistical relationships with local meteorological variables. In order to be more consistent with the observed time series variance, stochastic methods are used to falsely inflate the downgraded time series variance. Data from the Department of Drainage and Irrigation (DID) and the Malaysian Meteorological Department (MMD) will be used to forecast potential rainfall and temperature.

In order to start a statistical downscaling model, the data must first be turned into a quality control mechanism. The data will be checked to find the information of the data such as missed valued, minimum, maximum, mean, etc. This step would be the first to verify that the data is valid for use of this statistical downscaling model.

After completion of the first phase, the analysis will progress to the second process of screening the predictor variable. The key aim of the Screen Variables procedure is to assist the user in choosing appropriate downscaling predictor variables. This is one of the most difficult stages in the creation of any mathematical downscaling model, as the choice of predictors essentially determines the essence of the downscaling climate scenario. The decision-making mechanism is also affected by the fact that the predictive capacity of individual predictor variables varies both spatially and temporally. Screening Variables facilitates the study of seasonal differences in predictor capacity.

Then we proceed to the calibration operation model. The Calibrate Model operation is based on the User–specific forecast and a range of Predictor variables, which computes multiple regression equation parameters using an optimization algorithm (either dual simplex of ordinary least squares). The User determines the model structure: whether monthly, seasonal or annual sub-models are required, whether the method is unconditional or conditional. In unconditional models, a direct relation between predictors and predictors is assumed. In conditional simulations, there is an intermediary phase between regional force and local weather.

After finish with the calibration model, the next step is to verify the data in weather generator. The function of the Weather Generator produces sets of synthetic regular weather. Series of observed (or NCEP re-analysis) atmospheric indicator variables. This is the technique allows the verification of calibrated models (using independent data) and synthesis of artificial time series on real atmosphere conditions. The User selects a configured model and SDSM automatically attaches all the appropriate predictors to the model weights. The Applicant must also determine the time of the submission. Record to be synthesized as well as the number of ensemble members demanded. Synthetic time series are written to individual output files for later statistical analysis, graphing and/or simulation of impacts.

Afer that we proceed to the data analysis. SDSM provides a way of interrogating all downscaled and experienced situations. In both instances, the User must determine the sub-period, the output file name and the statistics picked. The ensemble member or mean must also be used for model performance It's mentioned. In exchange, the SDSM shows a suite of diagnostics, including monthly/ seasonal/ annual means, dispersion measures, serial correlation and extremes. Climatic data with summary figures and frequency analysis screens

SDSM 4.2 offers three methods for graphical analysis with the Frequency Analysis, Compare Outcomes and Time Series Analysis displays. The Frequency Analysis panel helps the user to plot the extreme value statistics of the selected data file (s). The analyzes shall contain Analytical, Gumbel, Stretched Distributions of Exponential and Generalized Extreme Value. The Compare Results screen helps the User to plot the monthly statistics provided by the Summary Statistics screen. Once the appropriate input file has been specified, either bar or line charts may be selected for display purposes.

Graphing Choices allows simultaneous analysis of two data sets and thus quick estimation of downscale versus observed or current versus future climate scenarios.

Finally, the Scenario Generator process generates synthesized regular sets of generators. Weather series focused on atmospheric predictor variables provided by the climate model (either for actual or future temperature experiments) rather than for the predictors found. This function is similar to the operation of the Weather Generator in all respects except that it might be appropriate to define a separate convention for model dates and the source directory for predictor variables. The input files for both the Weather Generator and the Scenario Generator options do not need to be the same length as those used to achieve model weights during the calibration process.

3. Results and Discussion

- Calibrate and Validate temperature

Comparison of the observed data with the modelled HadCM3-A2 findings Figures 4 and 5 are shown. The graphs indicate that the chosen predictors were well associated with the local prediction and provided very similar simulation results at the observed temperature. However, the calibrated minimum temperature is calculated to be significantly lower than the reported temperature during April to August with a difference between 0.04 °C to 0.46 °C. In the meantime, the calibrated maximum temperature and the validated maximum temperature created a similar pattern, whereby the simulated temperature was higher than the observed value for January to December.

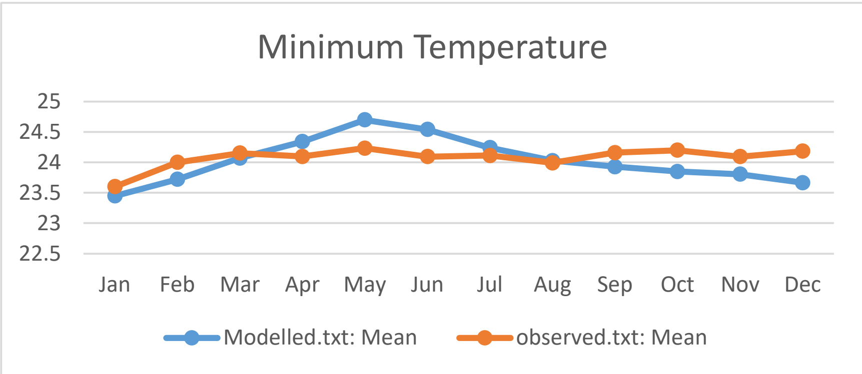

Figure 4: Result of calibration and validation (2010 to 2019) minimum temperature at Ibu Bekalan Jelai Station using SDSM model

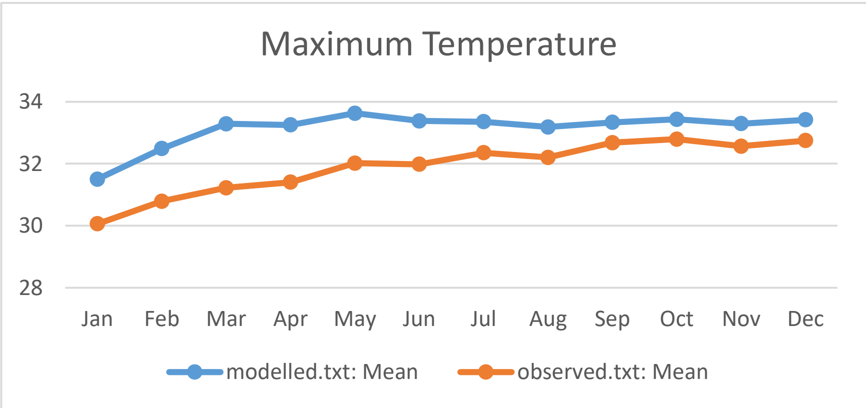

Figure 5: Result of calibration and validation (2010 to 2019) maximum temperature at Ibu Bekalan Jelai Station using SDSM model

- Calibrate and validate rainfall

Calibration and validation of rainfall using NCEP variables are seen in Figure 6 for Ibu Bekalan Jelai station in the sub basin of the Kurau River. The calibration took place and confirmed from 2010 to 2019. The chosen predictors was able to model connections with local stations. Figure 7 shows the result for calibrate and validate data on Ibu Bekalan Jelai station from 1961to 1990 which referring the previous research. As we can see, there are unstable result for modelled and observed in 2010 until 2019 but different with result in 1961 to 1990 which is more stable. One of the possibility that can be related is the predictor used is not suitable for the predictant.

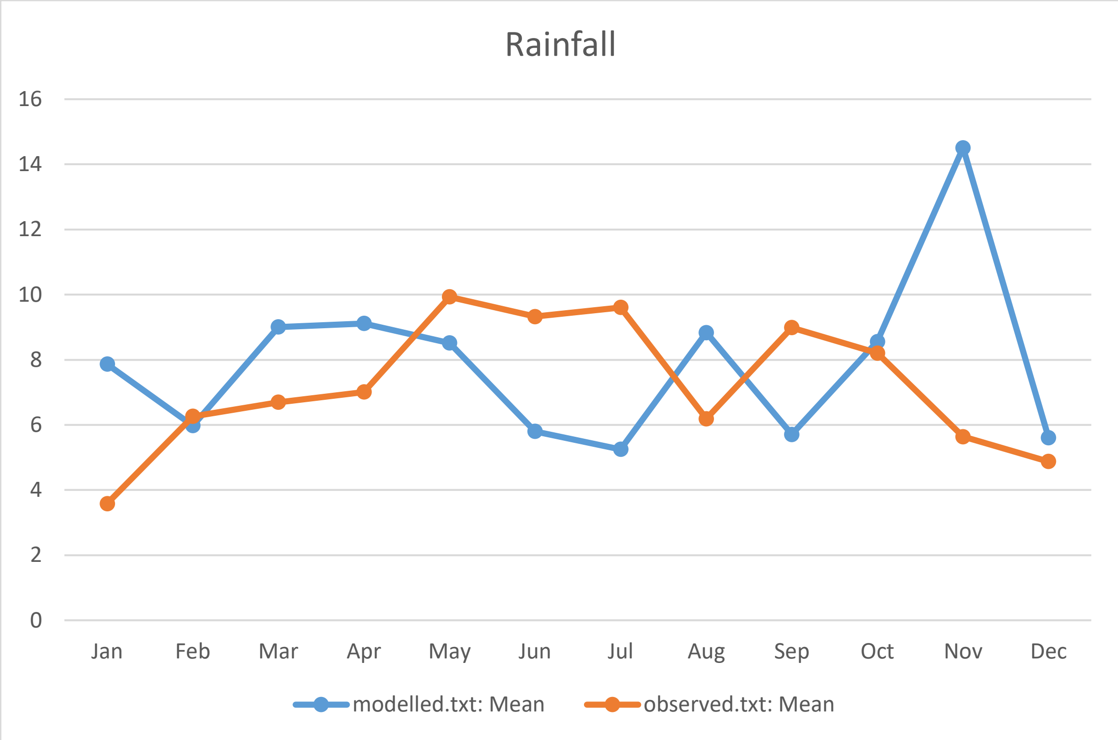

Figure 6: The calibrated and validated result of rainfall in (1961-1990) and (2010-2019)

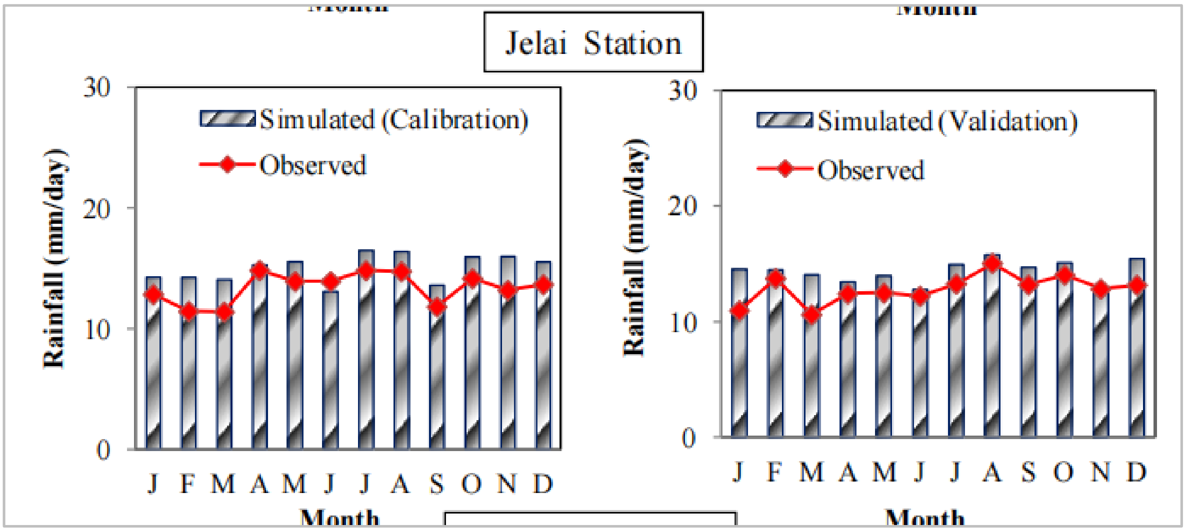

Figure 7: The calibrated and validated result of rainfall in (1961-1990) and (2010-2019)

- **Future Rainfall**

The generated rainfall during year 2020 to 2050 is depicted in Figures 8 and Table 1. The results present the average monthly temperature for every interval year period; 2025 – 2034 (2030s), 2035 –

2044 (2040s), and 2045 – 2055 (2050s). The rainfall is expected to rise at the end of century achieving 110 mm/day.

The projection of rainfall from period 2025-2034 shows a decreased 11.33 mm/day and then increased until the end of the year. The period 2035-2044 shows decrease 15.47 m/day and 2045-2054 shows a decrease of 18.0 mm/day. The increment of rainfall occurs in April.

The rainfall results show the increment on January until Mac in the readings. The results show that the average rainfall will continue to rise from April until December. A highest rainfall is predicted to occur in May, June, August, October and November that may be affected by the interchange of northeast monsoon to the south-west monsoon. Precaution is highly recommended even though the estimated rainfall in the future is not extremely high. It is because the rainfall raises may encourage the loss of volume of soil moisture and evapotranspiration rate especially at open surface, such as paddy fields. [4] stated that the projected value for future lack exact values because it occurs in the future, but these results can be compared with those from similar studies. These results were supported by the Malaysian Meteorological Department, Malaysia report, which revealed that the increment of the projected temperature in Peninsular Malaysia at the end of century using Statistical Downscaling Model.

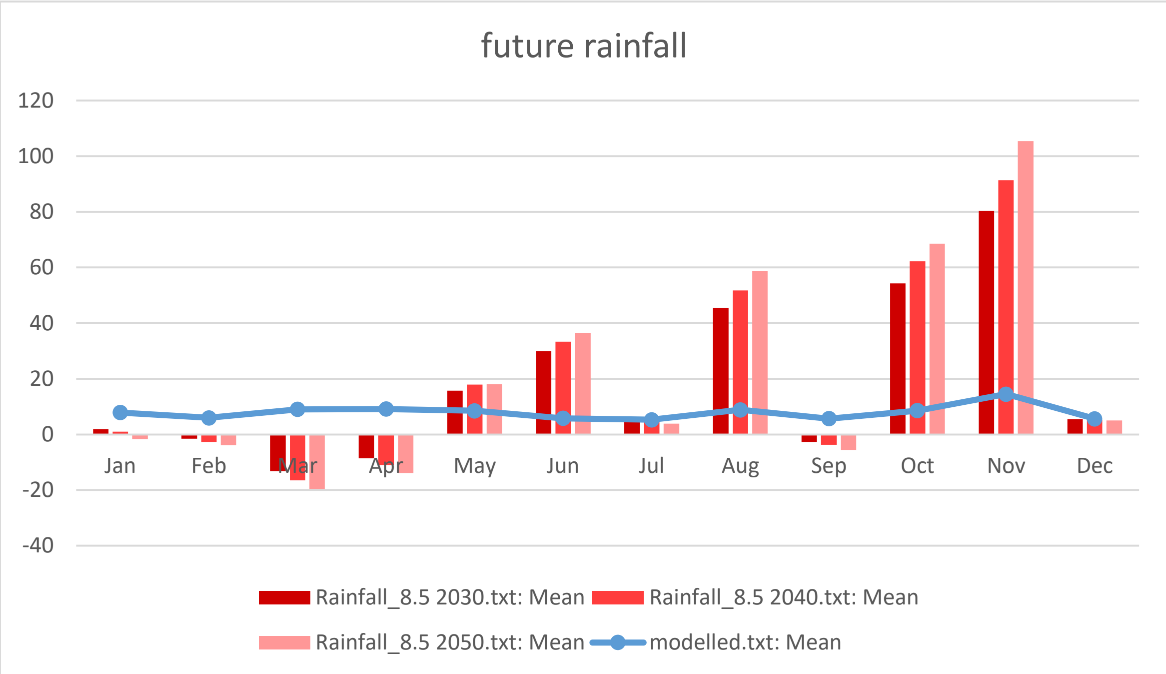

Figure 8: Future rainfall data for 2030, 2040, and 2050

Table 1: Average future rainfall data for every month from 2020 until 2050

	modelled.txt: Mean	Rainfall_8.5 2030.txt: Mean	Rainfall_8.5 2040.txt: Mean	Rainfall_8.5 2050.txt: Mean
Jan	7.86573	1.89097	1.03342	-1.6762
Feb	5.97545	-1.52763	-2.72331	-3.85826
Mar	9.00344	-13.2222	-16.4989	-19.6717
Apr	9.11502	-8.57461	-11.0464	-13.8497
May	8.51605	15.7335	17.9413	18.0615
Jun	5.80094	29.8512	33.3683	36.4836
Jul	5.24892	4.49354	4.4071	3.85226
Aug	8.83406	45.4434	51.7413	58.6478
Sep	5.70397	-2.71047	-3.76768	-5.59623
Oct	8.55674	54.2968	62.2109	68.6047
Nov	14.5076	80.339	91.3875	105.368
Dec	5.60978	5.46693	5.11238	4.99306

- **Future Temperature**

Statistical Downscaling Model (SDSM) have produced certain types of data such as Maximum Temperature, Minimum Temperature, and rainfall. After calibrate and validate the data, the next step is predicting the rainfall data, minimum and maximum temperature fo 2030, 2040 and 2050. Different data result gives different types of graph pattern as shown in the figures below. The generated temperature in terms of minimum and maximum during year 2020 to 2050 is depicted in Figures 3.7 and 9 and Table 2 and 3. The results present the average monthly temperature for every interval year period; 2025 – 2034 (2030s), 2035 – 2044 (2040s), and 2045 – 2054 (2050s). The maximum temperature is expected to rise at the start of century achieving 34.6 °C. The minimum temperature is consistent below 26 °C with the average increment.

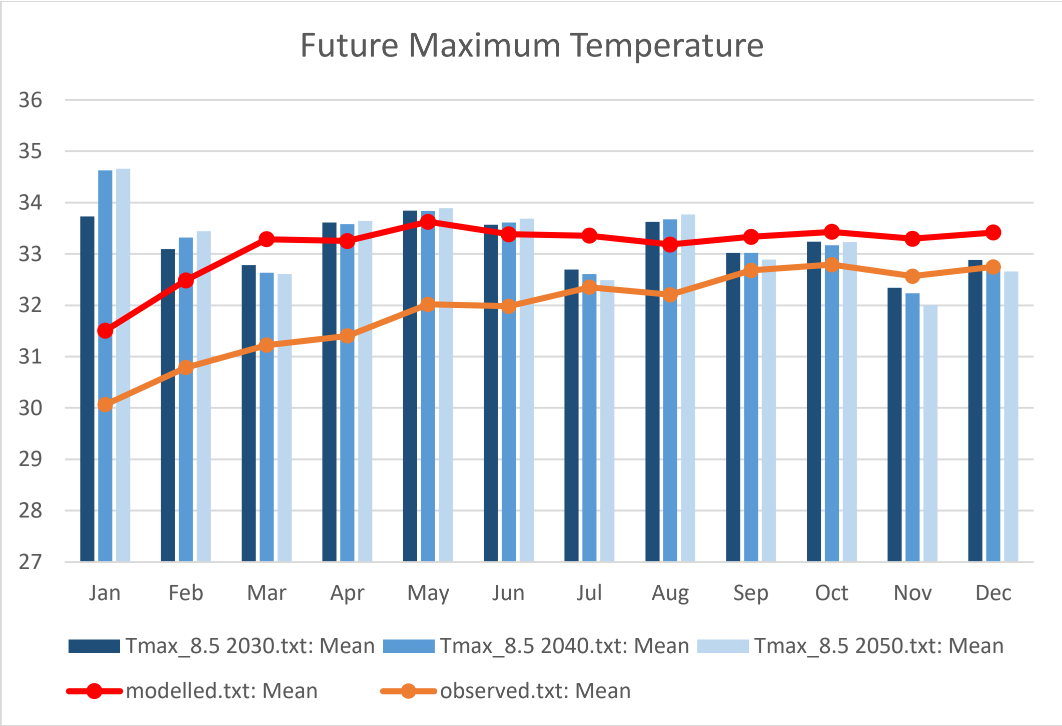

Figure 9: Average future maximum temperature in 2030, 2040, and 2050

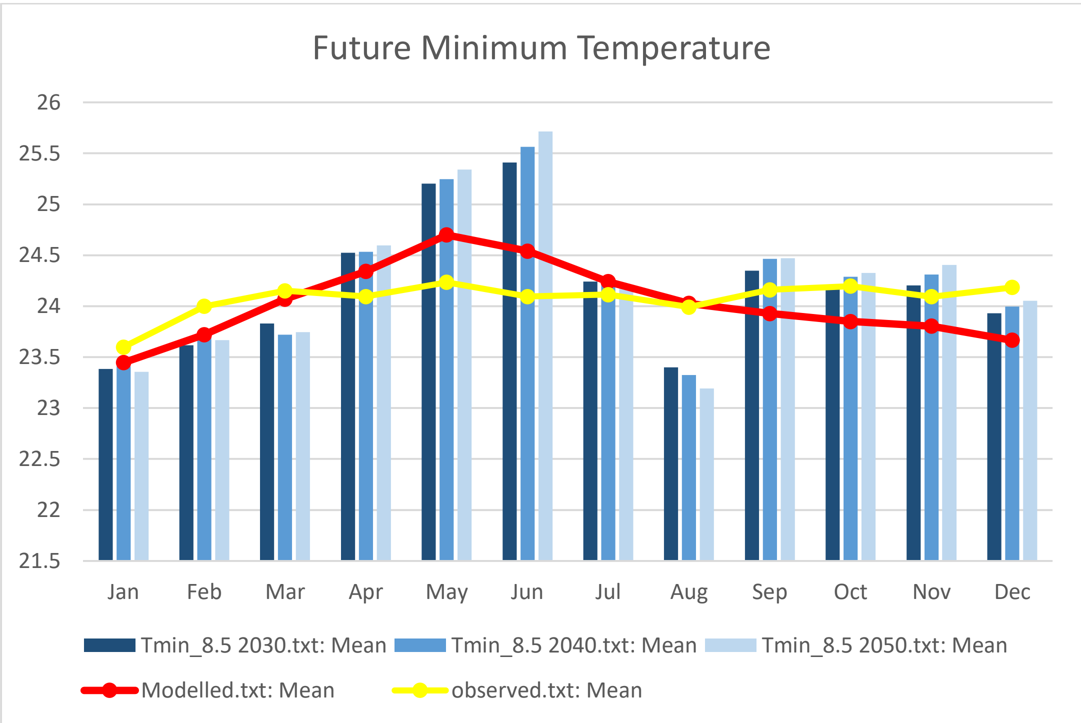

Figure 10: Average future minimum temperature in 2030, 2040, and 2050

Table 2: Future Maximum rainfall data monthly in 2030,2040 and 2050

	Tmax_8.5 2030.txt: Mean	Tmax_8.5 2040.txt: Mean	Tmax_8.5 2050.txt: Mean
Jan	33.7336	34.6303	34.6608
Feb	33.0978	33.3185	33.4463
Mar	32.7804	32.6313	32.6114
Apr	33.6136	33.5819	33.643
May	33.8445	33.8366	33.8922
Jun	33.5694	33.6122	33.6846
Jul	32.6957	32.607	32.4875
Aug	33.6255	33.6737	33.7714
Sep	33.023	33.0232	32.8865
Oct	33.2387	33.1689	33.2344
Nov	32.3425	32.2363	32.0026
Dec	32.8843	32.7873	32.6613

Table 3: Future minimum rainfall data monthly in 2030,2040 and 2050

	Tmin_8.5 2030.txt: Mean	Tmin_8.5 2040.txt: Mean	Tmin_8.5 2050.txt: Mean
Jan	23.3846	23.4079	23.3572
Feb	23.6166	23.6965	23.667
Mar	23.8316	23.7212	23.7452
Apr	24.5255	24.5336	24.5954
May	25.2024	25.2471	25.3416
Jun	25.4108	25.5651	25.7136
Jul	24.2413	24.2466	24.2072
Aug	23.3986	23.3241	23.1937
Sep	24.3478	24.4649	24.4724
Oct	24.2061	24.2894	24.3252
Nov	24.204	24.3104	24.406
Dec	23.9319	23.9956	24.054

4. Conclusion

The effect of reduced rainfall did not represent any systemic trend in both time horizon spans in the future. The amount of rainfall indicates a diminishing pattern at the beginning of the year (January to March) and a growing trend towards the end of the year (April to November) from the current climate cycle. The growing trend persists throughout the transition season (March to April). While there is no well-defined pattern seen during the SW monsoon season (May to September), there is a general indicator that rainfall will increase in certain future time horizons in most of the months from the current period.

The SDSM model can generate a strong compromise between the simulated models and historical values during the calibration and evaluation process. Especially on rainfall, At the temperature however, a good bias adjustment should be made to ensure that the pattern is comparable to the data found.

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