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Climate Change Assessment on Flood Occurrence in Kota Tinggi, Johor

Nur Danisyah Anuar[1], Siti Nazahiyah Rahmat[1*]

[1]Faculty of Civil Engineering and Built Environment,
Universiti Tun Hussein Onn Malaysia, Batu Pahat, 86400, MALAYSIA

*Corresponding Author

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Abstract: Flood is associated with the climatic change where the climate variable has detrimental impact on hydrologic cycle. Johor is among the affected states by flood catastrophe for almost every year. Over the year, Johor has experienced increasing amount of rainfall. However, studies on future rainfall pattern in Johor are still quite limited. Thus, this study was carried out to identify climate change impacts by projecting rainfall data using Statistical Downscaling Model (SDSM) and predicting flood events utilizing the Standardised Precipitation Index (SPI). Through SDSM, the rainfall data was projected in corresponding with General Circulation Models (GCM) predictor under three different representative concentration pathway (RCP) of RCP2.6, RCP4.5 and RCP8.5 that consider different emission level in future. Future observation in the upcoming 30 years for both studied stations at Kota Tinggi, Johor recorded increasing trend in the projected mean annual rainfall under three scenarios where the highest change in projection was +12.2% under RCP8.5 at Ladang Telok Sengat station. From SPI analysis, it is predicted that there will be frequent occurrence of flooding in the upcoming 30 years due to more positive SPI values ($\geq$ 1) indicated by the studied stations. From the study, the authorities can come up with better mitigation plan to supervise the flood event in the future.

Keywords: Climate change, Statistical Downscaling Model (SDSM), Standardised Precipitation Index (SPI)

1. Introduction

Climate change has now become the major global environment issues that has significant impact towards nature and human life. Climate change are the changes in climate variability in long-term period due to global warming happened from anthropogenic activity. The rapid changes of climate affecting the hydrological cycle which lead to the occurrence of extreme weather events, increasing in mean sea level and irregular rainfall trends. It was reported that Malaysia experience the irregularities of precipitation due to climate change for almost three decades [1]. Extreme weather event such as flood is associated with climate variability due to climate variability has great influence to the rainfall trend that lead to the occurrence of flood when there is high amount of rainfall. Climate change also has the possibility to increase the risk of flooding and frequency of occurrence. Flood can occur in several hours or days depending on river condition or geographical factors. Practically, 9% of the total area in Malaysia are vulnerable to flood catastrophe and almost every year Malaysia experience numerous of flood event [2].

The General Circulation Models (GCMs) is known as recently developed and optimal tool that analyse global system and the prediction of future global climate change caused by continuous increase in greenhouse gases emission [3]. The GCM have the ability to access the climate change impact through the climatic variable information and for the prediction of climate change condition in the upcoming years. The raw outputs from GCMs can be in large grid scale between 250 km to 600 km hence the output cannot be measured directly to determine the hydrological effects at local scale. According to studies conducted in Philippines, this model is still lacking in terms of course resolution and the unpredictability in

**Corresponding author: nazahiya@uthm.edu.my*

retrieving the local scale including clouds, geographical condition and atmospheric characteristics [4]. Noor and Ismail [5] stated that the climate simulation outcomes from GCMs unable to give reliable information on spatial scales. Dynamical and statistical downscaling were the two major approaches of downscaling method.

Dynamical downscaling techniques are computationally comprehensive and requires data that cannot be easily available compared to statistical downscaling that need only precipitation data that always available across the region. The statistical downscaling has comparable accuracy and much simpler in the process of downscaling the GCMs outputs than dynamical downscaling [3]. Through this study, Statistical Downscaling Model (SDSM) was utilized to construct statistical link between the local scale and GCM scale. Various studies conducted demonstrate that SDSM is simple to handle and operate make it widely applied in the projection of climate change for future. In Perlis, studies by Hassan *et. al* [6] have known that the calibration process in SDSM is capable to downscale GCM outputs into finer scales based on the multiple regression equations. The daily precipitation information such as the predictand and the local scale of atmospheric which is the climate information as the predictor variable were involved in the multiple regression equations. Othman and Tukimat [7] indicated that the multiple regression method develop the predictand and predictor relationship. From this relationship, SDSM integrates data from GCMs predictor to downscale the daily precipitation data. From past studies conducted, the GCM simulation shows that SDSM is commonly used due to good performance when simulating and projecting daily rainfall data.

Standardised Precipitation Index (SPI) is well-known meteorological tool that are commonly utilized for the evaluation and monitoring of flood occurrence which consider the intensity of rainfall and rainfall period. SPI was developed by McKee *et. al* [8] to measure the loss or excess on rainfall at different time scales. The main advantages of this flood indices are the simplicity, flexibility and accessibility on precipitation data over a period of time and have the ability to monitor various states of time scales [9]. The variability of wet and dry period that represent different characteristics can be identified by SPI. Short term time scales can provide some insight about flood or drought event meanwhile long term time scales indicate the pattern of precipitation in long period of time that lead to the occurrence of flood [7]. SPI was designed for conveying the rainfall correlation by using rainfall probability function where the computation need long-term precipitation data to determine the possibility of distribution which then converted to normal distribution [10]. In addition, the only input for SPI is precipitation data which always available across the region. Hence, this paper focuses on the climate change impact towards the occurrence of flood in the upcoming 30 years through the projection of rainfall event using SDSM and the prediction of flood frequency through SPI at selected stations in Johor. This is due to throughout the year, Johor has received high amount of rainfall but the study related to future rainfall pattern are still quite limited.

2. Materials and Methods

The relationship between climatic variable and rainfall data was determined using Statistical Downscaling (SDSM) and Standardised Precipitation Index (SPI) for future rainfall pattern. All the methodology involved was explained in this section.

2.1 Study Area and Precipitation Data

Johor is one of the states in Malaysia located at the south part of Peninsular Malaysia that lies between the latitude of 1°48’N and longitude of 103°76’E which cover land area of 19,102 km^2. There are total of 10 districts in Johor with Johor Bahru serves as the capital state. Subsequently, the state of Johor experiences wet and warm climate all year around because of its geographical location at the equator line with average annual rainfall of 2600 mm. The cycle of climatic in this region is influenced by dual monsoon seasons which are the South-West monsoon season that occur between May to September and North-East monsoon season that lies between the month of October to March. The Southwest monsoon are usually leads to the occurrence of rain and affected the state of Johor which then lead to the flood event [11].

Kota Tinggi that is located at the east part of Johor state is among the districts that are badly affected by flood event for almost every year. Kota Tinggi consist of large watershed area and experience high amount of rainfall with annual average rainfall of 2470 mm. The study that are related to worst flood that occurred over large watershed due to the monsoon climates are poorly known and conducting comprehensive research is helpful to give an insight about climatic and hydrologic conditions of an area [12]. There are two (2) selected rainfall station at Kota Tinggi, Johor that are utilized to perform this research and to collect the rainfall data needed. The location of the station and the related information was as shown in Fig. 1 and Table 1 respectively. 30 years of monthly historical data from the year of 1988 to 2017 were applied for the analysis of future rainfall pattern in Kota Tinggi, Johor.

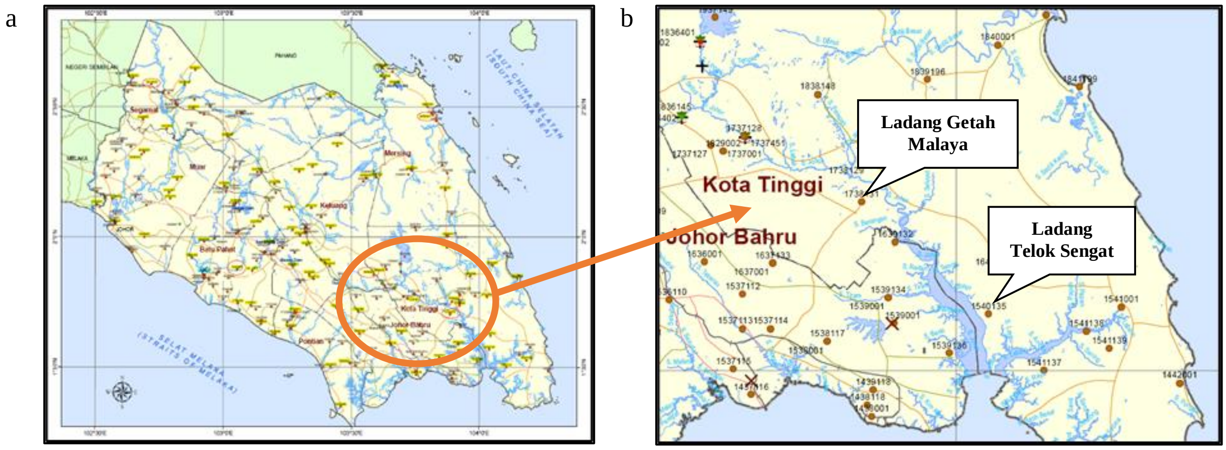


Fig. 1 - (a) Rainfall station in Johor; (b) Selected station in Kota Tinggi

Table 1 - Description of the selected rainfall stations

Station No	Station ID	Station Name	Latitude (N)	Longitude (E)
1	1738131	Ladang Getah Malaya	01 42 10	103 53 10
2	1540135	Ladang Telok Sengat	01 34 05	104 02 20

2.2 Statistical Downscaling Model (SDSM)

The GCMs are the optimal and reliable tool in projecting future climate variables. GCM are based on large grid scale between 230 km to 600 km. Thus, SDSM is capable to reduce the large grid scale to 5 km to 50 km which is resulting in more precision outcomes. The GCM was able to be downscaled by SDSM through multiple regression method. The precipitation data and the climate predictor were involved in the multiple regression equations. The accuracy of SDSM depends on the selection of predictor which the predictors must be able to be downscaled by GCM. Through this study, the changes in rainfall distribution because of climate variability in the selected station in Kota Tinggi, Johor were determined by the simulation of daily precipitation data to forecast the future pattern using GCMs predictor Coupled Model Intercomparison Project phase 5 (CMIP5).

Fig. 2 represents the method used in the downscaling rainfall data with climate predictor process through SDSM. The historical rainfall data from year 1988 to 2017 becomes the predictand and it was checked through “Quality Control” to ensure there is no missing values and no error detected in the rainfall data. The climate predictor was selected through “Screen Variables” tool. As the precipitation data was used, the model selected “conditional process”. The significance level used was 0.90. After the best five (5) climate predictor was chosen, it was calibrated under “Weather Generator” and “Scenario Generator” function. The calibration process is vital in order to determine the standard error on raw and observed historical data with selected climate predictor under “Weather Generator”. Meanwhile, the outcomes from “Scenario Generator” are future projected daily precipitation data in the upcoming 95 years from 2006 to 2100 where the year 2018 to 2047 were used as validation process. Thus, the analysis of forecasting rainfall event in the upcoming 30 years was performed in this study.

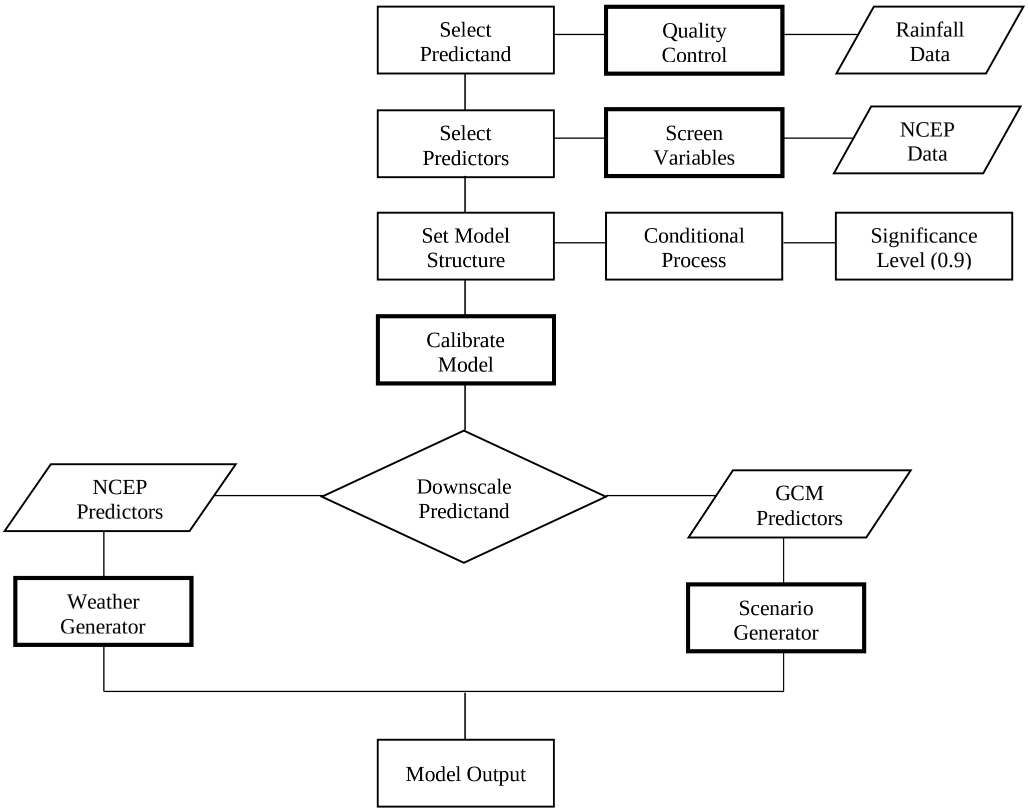


Fig. 2 - Process of downscaling rainfall data and climate predictor using SDSM

2.3 Retrieving Climate Predictor Variables

The climate predictor for both historical (NCEP) and future observations (GCM) that are used in this study were retrieved from websites that independently download the data by entering the coordinates of the rainfall station. The historical predictor (NCEP) were obtained from https://sdsm.org.uk/data.html that covers year from 1948 to 2017. The climate predictor for future observations were obtained from second-generation Canadian Earth and System Model (CanESM2) websites https://climate-scenarios.canada.ca/?page=pred-canesm2 that covers the year of 2006 to 2100.

2.4 Screening of Climate Predictor

The National Centre of Environmental Prediction (NCEP) climate variables were retrieved for the calibration and validation process of the downscaling method of SDSM. In order to determine the best climate predictor using multiple regression equations, SDSM was utilized. The NCEP predictors along with the observed rainfall data was screened in the "Screen Variables" function, calibrated through "Climate Models" and validated using "Weather Generator". The identification of the most appropriate predictor is vital as it can determine the result of the forecasted rainfall pattern. The best climate predictor can obtain the best guidance in forecasting process.

In this study, the coefficient of determination, R^2 was utilized to determine the fit of goodness between the observed data and modelled data. The analysis of correlation to check 26 predictors for the selection of best predictor correspond to the precipitation data (predictand) was carried out. The significance level of p < 0.05 (5%) can identify the most correlated predictor and predictand relation variables. R^2 value can investigate the variation in the observed data and calculated using Eq. 1.

$$R^2 = \frac{(\sum[X_i - X_{av}][Y_i - Y_{av}]^2)}{\sum(X_i - X_{av})^2 \sum(Y_i - Y_{av})^2} \qquad (1)$$

Where the X_i represents the observed data, X_{av} is the mean value of observed value, Y_i is the modelled data value and Y_{av} is the mean modelled data. The standard error (SE) for the studied rainfall station was computed as Eq. 2 to ensure the climate predictor selection is the best and most appropriate for the selected location. The ABS in the equation represent the absolute number which is positive in value.

$$SE = ABS\left[\left(\frac{Validation - Observation}{Validation}\right) \times 100\right] \quad (2)$$

2.5 Scenario Generator for Future Rainfall Projection

For projection of future rainfall, the GCMs predictor data set from CanESM2 that covers the year of 2006 to 2100 were retrieved. The same climate predictor (NCEP) that are chosen from the screening of best climate variables were used for the projection in SDSM. This is because the NCEP and GCM predictor have same types of parameter including mean sea level, temperature, geopotential height, humidity and others. The rainfall data range from 2018 to 2047 were used for the calibration process through "Calibrate Models" under three (3) Representative Concentration Pathways (RCP) scenarios which are RCP2.6, RCP4.5 and RCP8.5. The highest RCPs value represent the highest greenhouse gases emission. The calibrated data was then downscaled in "Scenario Generator" function for future rainfall pattern observations. The influence of climate change on the rainfall pattern in Kota Tinggi, Johor is observed from the findings of the forecasting results.

2.6 Standardised Precipitation Index (SPI)

The probability of certain location will experience wet period was presented by SPI. The SPI was created in order to quantify precipitation surpluses or deficits over varies time scales. Thus, SPI Generator application was utilized for the prediction of flood in the upcoming 30 years. As SPI is a simple and reliable tool, it only needs precipitation data over period of time to be the only input parameters. The rainfall data can be presented in daily, weekly or monthly according to the required outputs. SPI Generator have the ability to generate SPI value from the precipitation data parameters over selected time scales as different time scales provide different rainfall characteristics. The output of this application can generate the SPI data or value along with the frequency and drought period as options. The obtained SPI value which in positive or negative value will indicate different situation where positive value of SPI shows the flood occurrence meanwhile the negative value of SPI indicates the drought event happening.

3. Results and Discussion

3.1 Determination of Climate Predictors

After the determination of missing rainfall data and accessing the climate (NCEP) predictor through calibration process, it is vital to choose the best predictor that represent the predictor-predictand relation. The selection of predictor will varies depending on the geographical factor and the predictor and predictand properties. The "Screen Variables" function in SDSM was utilized for the selection of best five (5) climate variables from the total of 26 predictor obtained from the websites. Through this step, the expected variance and partial correlation value were used to determine the appropriate predictor at studied rainfall station. The predictor and predictand (precipitation value) relationship were explained through the statistical correlation and probability value (*p*-value) where the best predictor is chosen from the best correlation. The statistical correlation with lower *p*-value less than 0.05 (<5%) represent the better relationship between rainfall data and predictor variables [13]. It is vital to represent on how the predictor's properties affected the formation of local weather. Hence, the accuracy of projection data is determined by the strong bond between the predictors and predictand.

Table 2 indicates the selected predictor variables of NCEP for each selected station along with *p*-value that shows the best predictor-predictand correlation. The selected predictor for Ladang Getah Malaya were 500 hPa geopotential height (ncepp500), relative humidity at 500hPa height (ncepr500), relative humidity at 850hPa height (ncepr850), near surface humidity (ncepshum) and near surface air temperature (nceptemp). Meanwhile, for Ladang Telok Sengat, the chosen variables were 850hPa geopotential height (ncepp850), relative humidity at 850hPa height (ncepr850), near surface relative humidity (nceprhum), near surface humidity (ncepshum) and near surface air temperature (nceptemp). Several studies conducted shows that geopotential height (ncepp) meet the requirements for predictions of precipitation value [14]. Other studies stated that amount of precipitation may affect the variation in the selection of predictor for rainfall station where specific humidity (shum) and relative humidity (rhum) were the most crucial factor on precipitation at most rainfall station. These two parameters are related to the occurrence of precipitation [15]. Hence, it shows that the screening of predictors is important which then form rainfall equation at each station in order to get useful prediction rainfall data value in the upcoming years.

Table 2 - The selected predictor for each rainfall stations

Station No	Station Name	Predictor Variables	Predictor Names	*p*-value
1738131	Ladang Getah Malaya	ncepp500	500hPa geopotential height	0.0023
		ncepr500	Relative humidity at 500hPa height	0.0439
		ncepr850	Relative humidity at 800hPa height	0.0009
		ncepshum	Near surface humidity	0.0035
		nceptemp	Near surface air temperature	0.0000

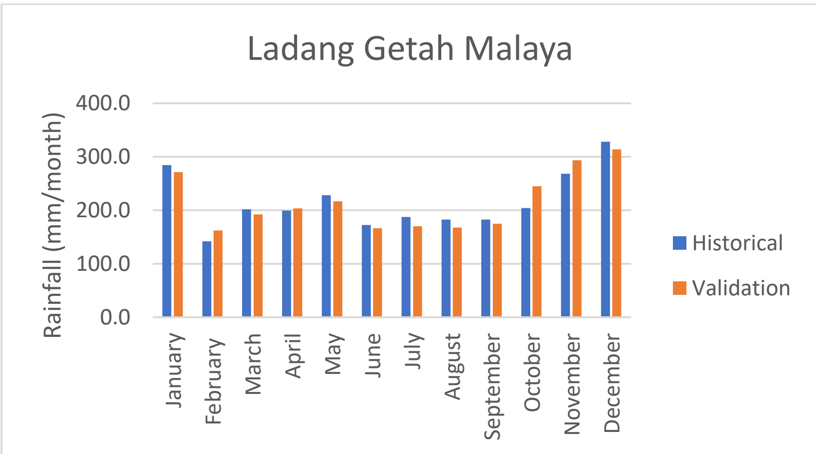
1540135	Ladang Telok Sengat	ncepp850	850hPa geopotential height	0.0391
		ncepr850	Relative humidity at 850hPa height	0.0000
		nceprhum	Near surface relative humidity	0.0394
		ncepshum	Near surface humidity	0.0027
		nceptemp	Near surface air temperature	0.0000

3.2 Calibration and Validation Process of SDSM

30 years of rainfall data set were divided into two 15 years data which were 1988 to 2002 and 2003 to 2017 for calibration process in SDSM to determine the relationship between the selected predictor and the observed rainfall data. Daily precipitation record (predictand) and NCEP climate predictors of 15 years data set were downscaled by the calibrate model tools using the model type of annual and conditional as the precipitation amount depends on the occurrence of wet or dry days [13]. Coefficient of determination, R^2 was the factor considered during calibration to evaluate the statistical performance of calibrated data with daily rainfall data. The R^2 value demonstrates on how well the relationship between the projected value from prediction model and the real-world data. The value obtained shows that SDSM is reliable in rainfall simulation for the selected station. The data set from calibration process are used for validation purposes to get more realistic results.

Validation was performed due to uncertainty from location based may be consistent but from other source it may lead to inaccurate results. The "Weather Generator" function was utilized for the validation process of selected climate variables after calibration. Weather generator function have the ability to generate series of daily precipitation from NCEP predictor and the regression models weight generated by the calibrate model where it allows the verification of calibrated models. The synthesized data will represent the real weather condition. The findings from the validation process for each rainfall station was determined by calculating the average and the variation in rainfall data by making comparison between validation results of historical data obtained from SDSM software for year of 1988 to 2017 with observed historical data obtained from Department of Irrigation and Drainage (DID) of the same year. Fig. 3 represents the comparison between historical data from SDSM and DID within the study period of 1988 to 2017. It is seen that the result of the simulated and observed data resulting with quite similar rainfall pattern with less monthly biases. The high amount of precipitation occurred during the month of October to December along with January that also experienced high amount of precipitation. Therefore, the findings from SDSM were considered acceptable as the value almost matched and proven the SDSM performance in the simulation of rainfall.The SDSM performance during validation was also measured by the standard error (SE) of the estimated values. SE value with less than 0.23 (23%) represent good validation results as small SE value shows that predicted rainfall value resulting in equal or the value close to the observed rainfall. Both studied stations in Kota Tinggi, Johor obtained low SE value of 4.50% for Ladang Getah Malaya and 4.40% for Ladang Telok Sengat. Table 3 represents statistical value obtained from SDSM software which are the coefficient of determination (R^2) from calibration process and calculated SE value from the validation results.

a



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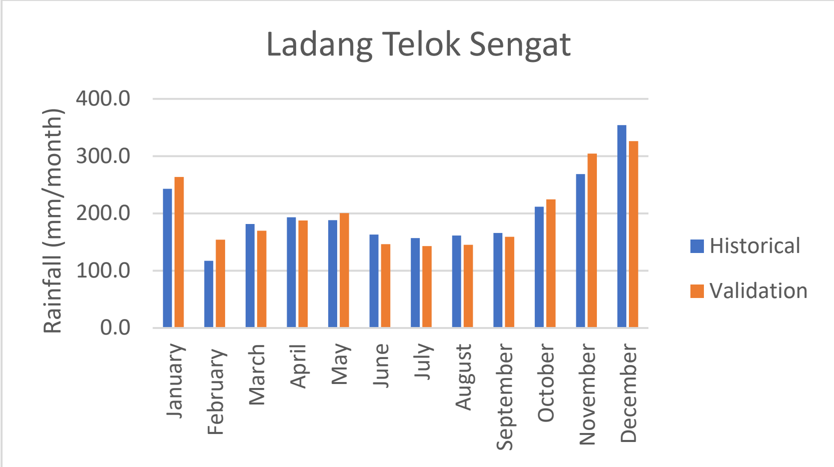


Fig. 3 - Comparison of observed and validated rainfall value for (a) Ladang Getah Malaya; (b) Ladang Telok Sengat

Table 3 - Statistical value from calibration process

Station No	Station Name	Coefficient of determination, R^2		Standard Error (SE)	Percentage of SE (%)
		1988-2002	2003-2017		
1738131	Ladang Getah Malaya	0.018	0.014	0.045	4.50
1540135	Ladang Telok Sengat	0.021	0.024	0.044	4.40

3.3 Future Projection of Rainfall

The future projection of rainfall pattern in the upcoming 30 years from 2018 to 2047 was performed using the selected climate variables produced by GCMs under scenarios of RCP2.6, RCP4.5 and RCP8.5. The GCMs predictor was downscaled using "Scenario Generator" function which the outputs are daily weather data from year of 2006 to 2100. Daily precipitation data from 2018 to 2047 were used for the projection results. The projection of change in the mean annual data under three different scenarios of RCP with simulated historical data as illustrated in Fig. 4. For Ladang Getah Malaya station, there is increasing trend in the projected mean annual rainfall where the change in projection are +3.3%, +5.7% and +8.9% for RCP2.6, RCP4.5 and RCP8.5. The selected climate predictor of ncepp500, ncepr500, ncepr850, ncepshum and nceptemp gives an impact to the increasing trend in the upcoming 30 years for this station. The findings for each RCPs described that the occurrence of rainfall expected to be increased in the upcoming 30 years period for Ladang Getah Malaya station since all scenarios resulted in increasing rainfall value. For Ladang Telok Sengat station, the mean annual rainfall in the upcoming 30 years period for each RCPs was forecasted to rise by +10.6% for RCP2.6, +10.8% for RCP4.5 and +12.2% for RCP8.5. The rainfall indices are predicted to be associated with the selection of predictor, hence the chosen climate predictor of ncepp850, ncepr850, ncephum, ncepshum and nceptemp causes the increasing value of mean annual rainfall for the year 2018 to 2047.

SDSM performs well in the downscaling process of daily precipitation data across the two (2) stations in Kota Tinggi, Johor. The regression model equation resulting from the correlation between observed precipitation and the climate predictor was presented through the results of this study. It was predicted that more extreme weather event such as extreme precipitation and flood may happen in the future as both studied rainfall stations recorded increasing amount of average rainfall annually. The increasing in projection value of annual rainfall by using SDSM also can be seen through a study conducted by Tarmizi *et. al* [1] about rainfall projection at varies station in Johor. The study resulted with the annual rainfall was projected positively for RCP2.6, RCP4.5 and RCP8.5 with the highest projected value is +15.5% under RCP8.5. Another study in Johor by Rahmat *et. al* [16] also shows that more extreme rainfall event will happen in future due to the increasing amount of rainfall under different RCPs especially in the district of Kota Tinggi, Kluang and Johor Bahru. Thus, the projection of the climatic information along with rainfall data in long term period is an important data that contributes to design, plan and manage the water supply and hydrological systems. The compatibility and accuracy of climate projection can be helpful for future development of district or state.

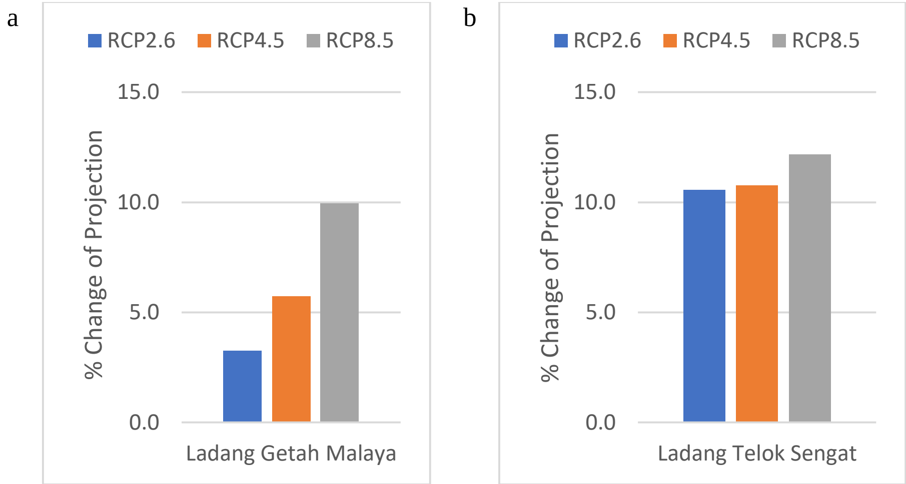
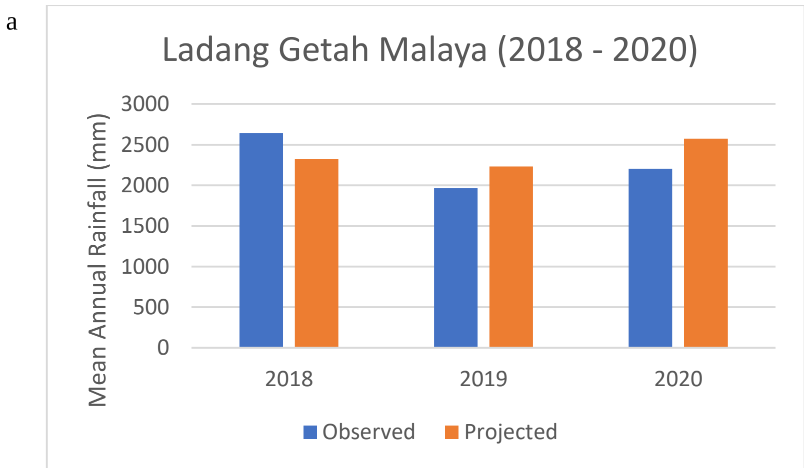


Fig. 4 - Percentage change of projection under different RCP scenarios (a) Ladang Getah Malaya; (b) Ladang Telok Sengat

3.4 Comparison between Annual Observed and Forecasted Rainfall

The future observation of rainfall pattern downscaled by SDSM was compared with the actual observed result from Department of Irrigation and Drainage (DID) for the year 2018 to 2020. The results obtained shows that the annual projected value from SDSM had quite similar pattern with the observed value from DID. Fig. 5 illustrates the comparison between annual observed and forecasted rainfall for year 2018 to 2020. For Ladang Getah Malaya station, the annual observed and projected rainfall are 2645.9 mm and 2326.5 mm respectively in year 2018. Meanwhile for year 2019, the mean annual observed value is 1967.2 mm and the predicted value is 2230.2 mm. The mean annual value from DID for year 2020 is 2202.6 mm and the forecasted value from SDSM is 2573.0 mm. According to the observation, there is slightly difference between the observed and forecasted precipitation value but the increasing value of forecasted rainfall by SDSM represent that the probability of extreme rainfall in the upcoming years is high which proven by the rainfall value from DID.

During the year of 2018, the average annual observed and projected precipitation at Ladang Telok Sengat are 2487.9 mm and 2537.5 mm respectively meanwhile the annual mean precipitation and forecasted value in year 2019 are 1696.5 mm and 2434.5 mm. For year 2020, the annual observed value is 2063.9 mm and the annual predicted is 2289.1 mm. For this station, the annual observed rainfall shows slightly lower than the annual forecasted rainfall but the high value of forecasted rainfall shows that SDSM is a reliable tool and a good statistical climate model that specialized in predicting future rainfall data. Thus, in the upcoming years, the effect of extreme rainfall event such as flood can be managed accordingly through downscaling method of climate model.



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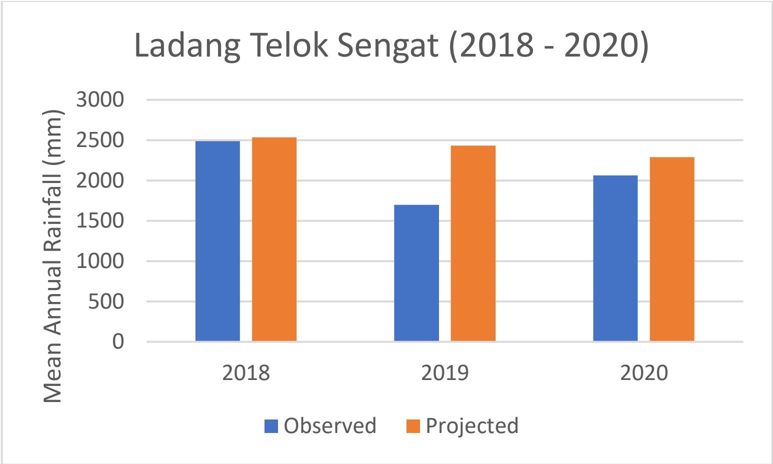

Fig. 5 - Comparison between observed and projected rainfall in 2018 to 2020 (a) Ladang Getah Malaya; (b) Ladang Telok Sengat

3.5 Projection of Flood Using SPI

The SPI was utilized to access the frequency and intensity of flood in the upcoming 30 years (2018-2047). Daily precipitation data from selected rainfall station was downscaled by GCM and was used for projection purposes. The dry and wet period were determined from the positive and negative value of SPI where positive SPI value indicates wet period meanwhile negative SPI value indicates dry period. Various time scales can be used for computation of SPI which ranged from 1,3,6,9,12,24,36 and 48 months but in this study the 12-month time scales were considered. This is because the 12-month time scales represent long term precipitation patterns. The frequency of dry and wet event for the studied station was presented in Fig. 6.

At Ladang Getah Malaya station, the positive value of SPI with more than 1 that shows the wet period was presented in the red-shaded region in Fig. 6. There are 195 positive SPI value from 360 number of observations which around 55% of the study period that indicates the wet period. Throughout the observation period, the highest SPI value was seen on the year of 2044 with SPI value of 2.29. According to McKee classification SPI value, 2.29 was categorized as extremely wet period which may contribute to flood event [9]. The climate change impact towards flood event was indicated through the correlation between the forecasted rainfall data from SDSM model and the positive SPI value. From SDSM model, the projected annual rainfall for year 2044 is 2976.9 mm which is considered as high amount of rainfall. This shows that in the year 2044, the high amount of projected rainfall can directly cause the flood occurrence which supported by the positive and high SPI value obtained. The majority findings for this station resulting in more wet event occurred frequently.

Ladang Telok Sengat station shows 52% of the study period resulting in positive SPI value which shows that 187 from 360 number of observations are the wetter period occurred at the station. From the graphical representation in Fig. 6, the highest positive SPI value is 2.39 in the year of 2020 which according to McKee SPI classification value was categorized as extremely wet period. The severity of wet period was shown in the red-shaded area on graph with positive value of more than 1. The projected rainfall value from SDSM model was correlated with the SPI value obtained where the annual projected rainfall for year 2020 is 2716.8 mm. The high rainfall amount and high positive SPI value usually associated with the probability of flood which are proven by the flood event occurred at the end of 2020 and early 2021 in Kota Tinggi, Johor. The flood occurrence is due to continuous heavy rain that lead to the submerged of roads and high number of evacuees [17]. Majority of the wet event occurred frequently during 2020 until 2041 for Ladang Telok Sengat station. Furthermore, the projection of flood frequency using SPI is vital for flood management and water resources management for upcoming 30 years.

In Malaysia, there are several researchers that utilizing SPI for the analysis of wet condition that contributes to flood event which important for flood mitigation purposes. In Terengganu, previous studies conducted by Fauzi *et. al* [9] reveals that the selected stations experienced extremely wet events for longest period with highest SPI values of 2.90 and the flood occurrence are expected to occur during the wet periods. Another study by Kamaruzaman *et. al* [18] regarding flood analysis in Peninsular Malaysia by using SPI where the one of the selected stations recorded highest annual mean rainfall of 3737.11mm and becomes the wettest area in Peninsular Malaysia.

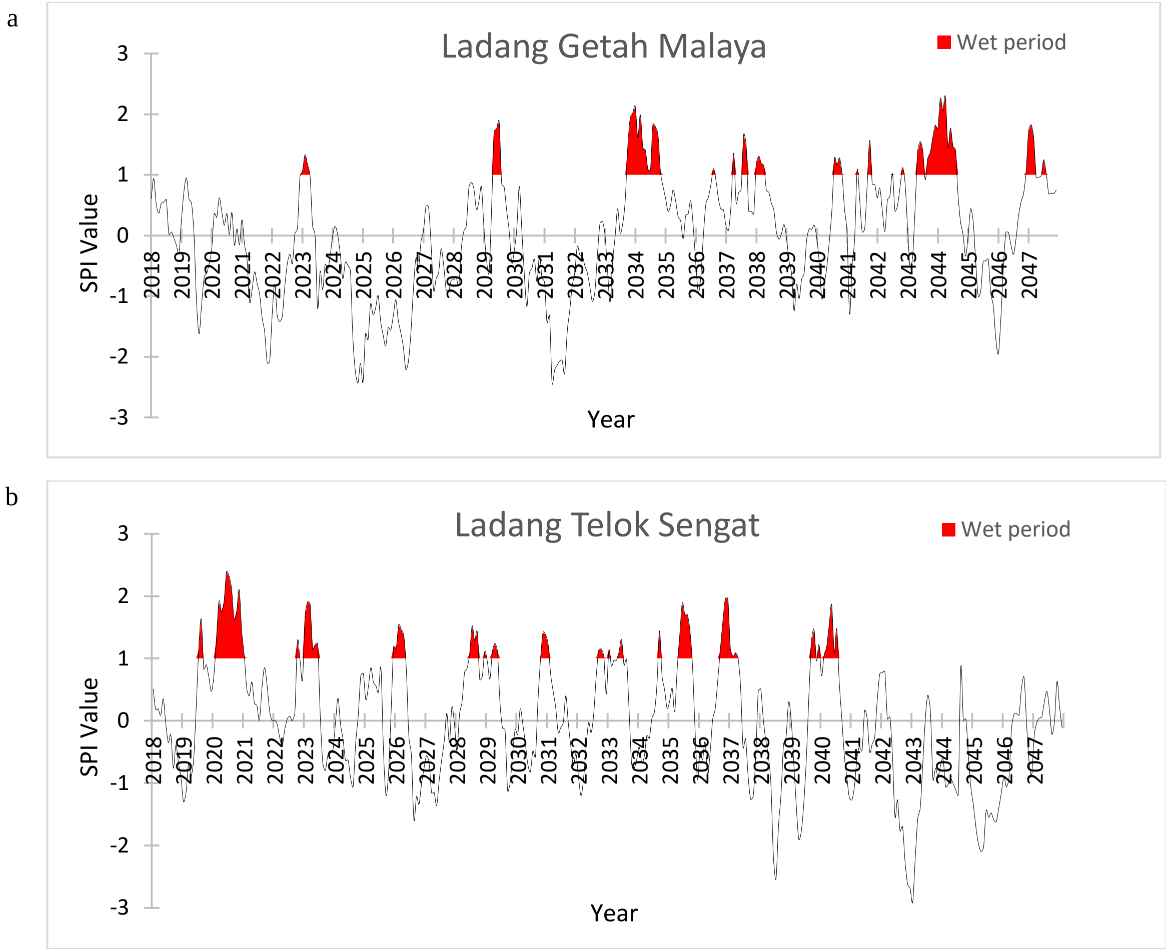

Fig. 6 - SPI value (a) Ladang Getah Malaya; (b) Ladang Telok Sengat

4. Conclusion

SDSM is a reliable tool and have the ability to downscale rainfall data by considering the climate predictor of NCEP and GCM that represent the current climate condition from the results obtained. The downscaling process of climate parameter is vital to investigate the climate change impact on rainfall pattern in the upcoming years. The simulation results indicated that Ladang Getah Malaya and Ladang Telok Sengat station recorded increasing in the rainfall trend under different scenarios of RCP2.6, RCP4.5 and RCP8.5. Hence, it is predicted that in the upcoming 30 years (2018 – 2047), Kota Tinggi district will experience extreme weather event such as prolonged rainfall and occurrence of flood event due to change in climate change by comparison to base period of 1988 to 2017. The outcomes of this study expected to be practical for the authorities to prepare better mitigation plan to adapt the impact of climate change in the future. Through the SPI analysis, the surpluses trend was detected on the monthly rainfall data for the upcoming 30 years (2018 to 2047). Hence, both studied stations indicated that for the upcoming 30 years, the station might experience wet period and predicted to associate with the occurrence of flood event. SPI able to demonstrate the precipitation severity over a selected time scales thus allowing to determine whether the station is experiencing flood or not. Therefore, the analysis of SPI in long term period can help to predict the frequency of flood in future and to be useful for water resource management that are related to climate change impact assessments.

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