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TECHNICAL NOTE

THE PROJECTION OF FUTURE RAINFALL CHANGE OVER KEDAH, MALAYSIA WITH THE STATISTICAL DOWNSCALING MODEL

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Abstract: Climate change is a crucial global issue. The trend of climate change is very important to the agriculture because its uncertainty may cause the reduction in crop yield and economic losses. Therefore, the climate model has been widely used to simulate the future climate variation based on atmospheric circulation pattern (predictors). This study utilized the Statistical Downscaling Model (SDSM). The purpose of this paper is to describe the climate variation in Malaysia's prominent agricultural state, Kedah, in the context of climate change scenario based on the temperature, rainfall intensity, wet and dry spell length. Twenty rainfall stations were selected in Kedah as they had lesser percentage of missing data to control the quality and capability of result. Based on the SDSM simulation result, the climate trend is not much different from the historical data but it is expected to increase continuously for every interval period from the year 2010 to 2099. The increasing of temperature is predictable up to 32^{o}C during south-west monsoon season and 40^{o}C during north-east monsoon season. The rainfall pattern shows that the intensity is estimated to focus on the middle area of Kedah such as Kota Setar, Pendang, Yan, Kuala Muda, Sik, and Baling district and is expected to increase during north-east monsoon season even when the wet spell during that period is relatively short. The longest dry spell which is expected to assault Kedah Peak and Kodiang in the future may cause water scarcity at critical areas.

Keywords: *Climate change, Statistical downscaling, Climate variation, Wet length, Dry length*

1.0 Introduction

Global climate change is assaulting the whole world and gives serious impact especially to the water storage management for agriculture, domestic and hydroelectric power supply. Based on (Karl *et al.*, 2009), climate warms are unequivocal and have become greater than over the last century. The major contributor is human activities such as burning of fossil fuel, clearing of forest, animal husbandry, agricultural practices and other activities that alter the original climatic changes.

Malaysia currently ranks 50th in the Climate Change Performance Index 2010 (CCPI, 2010), the index that shows the climate protection performance of every country according to their emission trend, emission level and climate policy. The result urges several drastic actions that should be taken by the corresponding authorities in enhancing the environmental quality.

Unfavorable climate to the agriculture sector such as longer period of drought and unexpected period of high rainfall intensity (flood) will cause low harvest, economic losses, and starvation among people. Therefore, the measurement and development of climate scenario in the agricultural area are necessary to control and manage water resources effectively. In Malaysia, the effect of climate change to the agricultural field and water resource still lack significant research and the level of awareness is still low. Therefore, the objective of this study is to reveal the future trend of climate change in the agricultural area of the Kedah state in year 2010 until 2099. The main reason for the choice of this region is that the area used to experience extreme flood and drought that seriously affected the paddy cultivation (staple food), ecosystem, and human health.

2.0 Material and Methods

2.1 Study Area

Kedah is an important agricultural state of Malaysia and is well known as the rice-bowl of Malaysia. It has the largest double cultivation paddy field (97,000 ha) which is the main food source among Malaysians. The location of this state is in the range of $5^0$10’ - $6^0$40’N latitude and $100^0$10’ – $101^0$10’E longitude to the north of Peninsular Malaysia. The area of this state is about 9,426 km^2 including twelve districts. Most of the land surfaces are relatively flat, making it a suitable place for paddy cultivation.

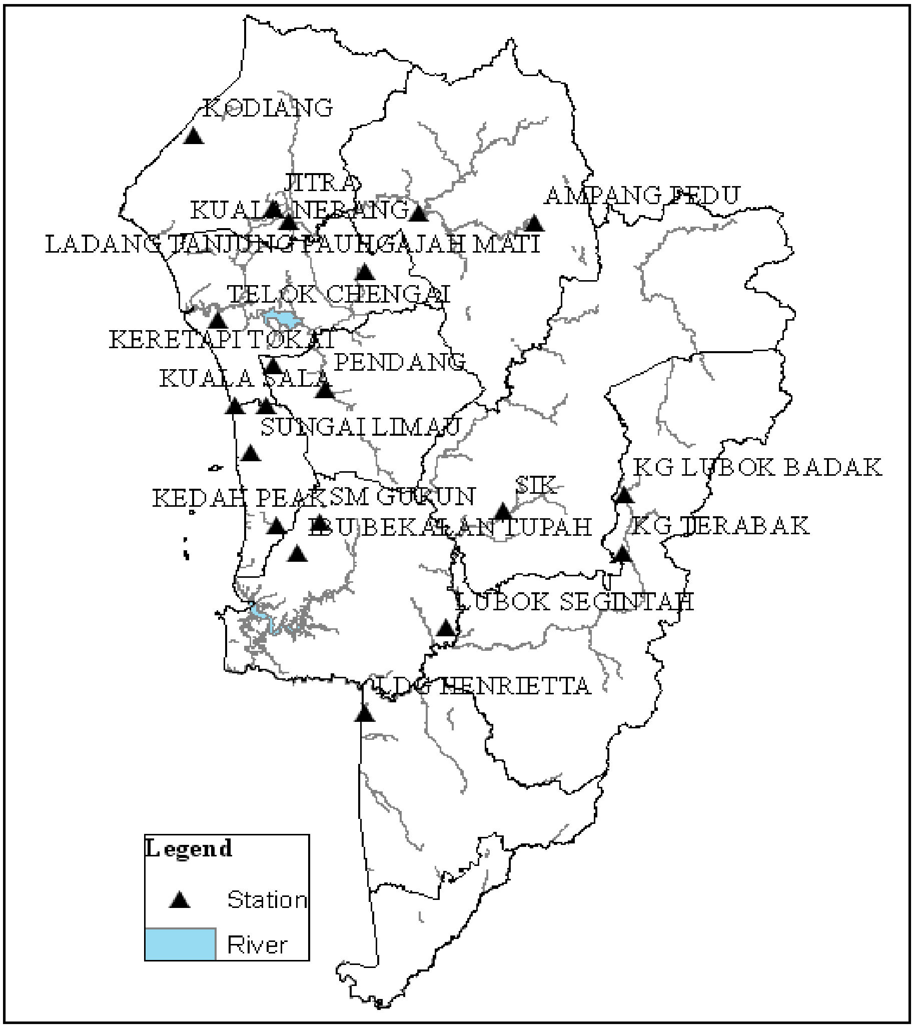


Figure 1: Kedah map and locations of 20 rainfall station

2.2 Historical Meteorology

Kedah is located near to the Malacca Strait. Therefore, the climate at this area is influenced by the seasonal wind flow patterns and the local topographic features. The changes of wind flow pattern in certain period result in four types of monsoon season, namely south-west monsoon season, north-east monsoon season and two shorter inter monsoon seasons. South-west monsoon season prevails in May until the end of September, otherwise known as the dry season, and North-east monsoon season prevails in November to March, also known as the wet season. During the inter monsoon season in April to October, the wind blows slowly in the range of 10-15 knot and inconsistently. The monthly rainfall patterns in this area are separated to primary (maximum and minimum) and secondary (maximum and minimum).

Referring to the historical data from year 1961 to 1990, the daily mean temperature in the study area was 27^{o}C to 32^{o}C. The highest monthly temperature focused on February to April where it achieved 34^{o}C and the lowest monthly temperature occurred from November to January in the average of 23^{o}C. The relative humidity fluctuated between 54 % and 94 % and the wind speed was in the range of 0 to 10 knots during normal weather.

The historical precipitation trend in year 1961-1990 showed that the rainfall distribution was non-uniform at this area. However, the rainfall pattern was almost similar for every year. The rainfall intensity increased from August to October (primary maximum) and April to June (secondary maximum). Nevertheless, the intensity reduced from June to July (primary minimum) and December to January (secondary minimum). The rainfall depth was about 16 mm/day, 127 mm/month and 2361 mm/year.

2.3 Methodology

Table 1 lists the twenty rainfall stations in Kedah used to obtain the rainfall pattern in the study area. The rainfall for every single location reacts as a predictand in statistical downscaling model. The rainfall station selection is based on the percentage of missing value (less than 10 %) to control the quality and reliability of the result. All these missing values were estimated using the Quadrant method because this method considers the distance of the gauge and density of the rainfall in calculation. The estimated missing rainfall at site *Y* by this method is:

$$P_t(Y) = \frac{\left(\frac{1}{d_A}\right)^2 P_t(A) + \left(\frac{1}{d_B}\right)^2 P_t(B) + \left(\frac{1}{d_C}\right)^2 P_t(C) + \left(\frac{1}{d_D}\right)^2 P_t(D)}{\left(\frac{1}{d_A}\right)^2 + \left(\frac{1}{d_B}\right)^2 + \left(\frac{1}{d_C}\right)^2 + \left(\frac{1}{d_D}\right)^2} \qquad \text{Eq. (1)}$$

where *d* is the distance between gauge *Y* and *Z* (where Z refers to *A, B, C, D* coordinate) and *P* is a quantity of rainfall at gauge Z during time *t*.

Table 1: Rainfall stations selected in Kedah

ID No.	Location	Coordinate
6105037	Gajah Mati	N 6° 11' E100° 32'
5704057	Ibu Bekalan Tupah	N 5° 45',E100° 27'
5704055	Kedah Peak	N 5° 48',E100° 25'
6004045	Keretapi Tokai	N 6° 02',E100° 25'
6302021	Kodiang	N 6° 23',E100° 18'
5904051	Kota Sarang Semut	N 5° 59',E100° 24'
5904043	Pendang	N 6° 00',E100° 29'
5803052	Sungai Limau	N 5° 54',E100° 23'
6004045	Telok Chengai	N 5° 54',E100° 23'
6204028	Ladang Tanjung Pauh	N 6° 14',E100° 26'
6206035	Kuala Nerang	N 6° 15',E100° 37'
5708071	Kg. Terabak	N 5° 45',E100° 53'
5807067	Sik	N 5° 49',E100° 44'
5808070	Kg. Lubok Badak	N5° 50',E100° 54'
5606077	Kg. Lubok Segintah	N5° 50',E100° 54'
5903151	Kuala Sala	N 5° 59',E100° 21'
5505084	Ladang Henrietta	N 5° 59',E100° 21'
5704056	SM Gurun	N 5° 48',E100° 28'
6204023	Jitra	N 6° 15',E100° 25'
6207032	Ampang Pedu	N 6° 15',E100° 47'

Two types of climate predictors at the grid box 28X x 33Y were used in the statistical downscaling procedure. The first type was the National Centre of Environmental Prediction (NCEP) reanalysis data set from 1961 until 1990 for calibration (1961-1975) and validation process (1961-1990). The second type was the GCMs predictors, namely Hadley Center General Circulation Model (HadCM3) of A2 scenarios (1961-2099) for projection climate scenarios. A2 scenario is a slower scenario that refers to the regional resiliency in terms of continuous increment in global population and energy consumption, compiled with moderately high intensity of land use. Consequently, the resources become scarce and the technological change is also fragmented.

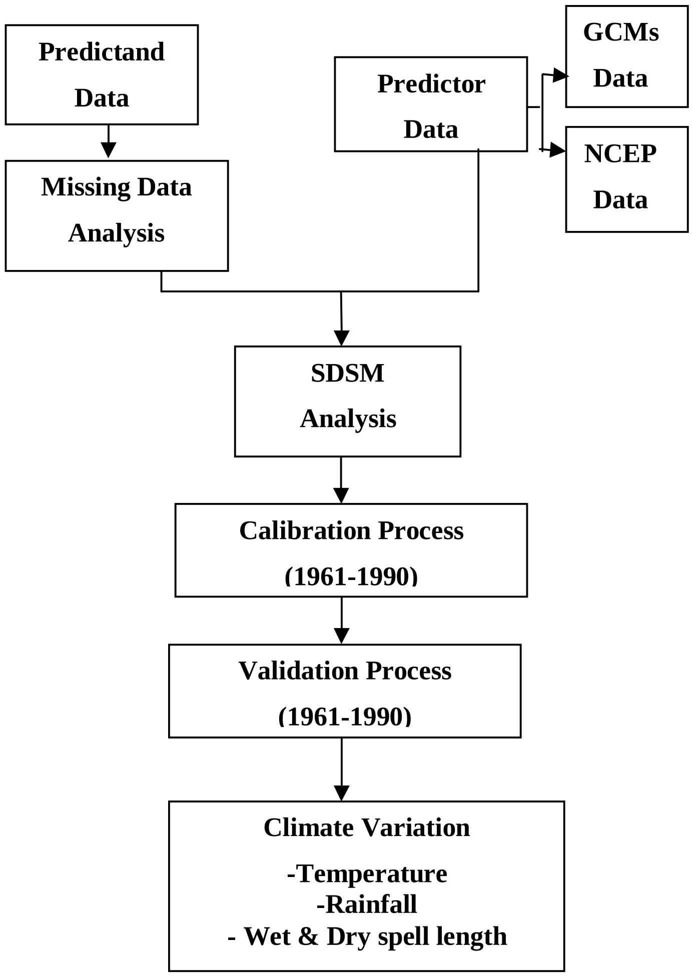


Figure 2: The sequence of study.

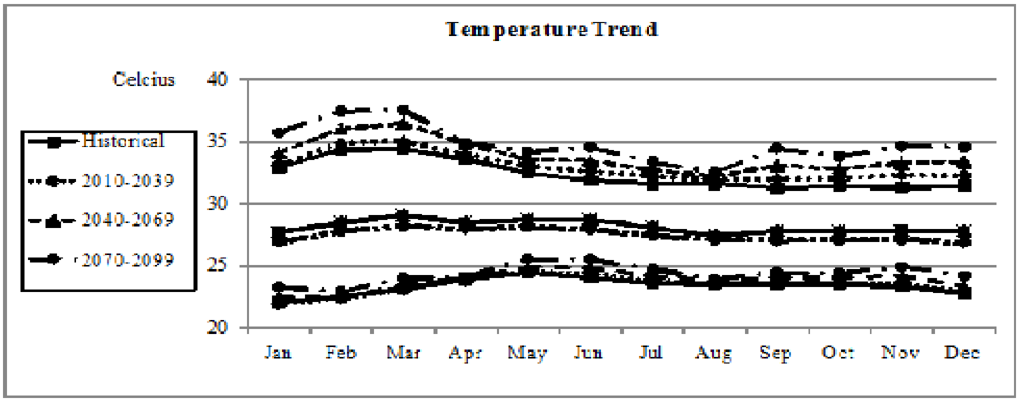
2.4 Statistical Downscaling

Statistical Downscaling model (SDSM) has been applied in many studies according to the climate simulation analysis in the future developed by Robert L. Wilby and Christian W. Dawson from United Kingdom. This model is widely used in the context of hydrological issue due to various climate scenarios because it provides station scale climate information from the grid resolution GCM-scale output using multiple regression techniques. Furthermore, the SDSM tools are computationally undemanding, low cost, simple and easily accessible compared to dynamical downscaling (Wilby *et al.*, 2002).

3.0 Result and Discussion

3.1 Temperature Pattern

The simulation of temperature data refers solely to the Alor Setar station to represent the whole area of Kedah. In year 2010-2039, the maximum temperature is expected to be within a range of 32 to 35°C and the minimum temperature will be in the range of 22 to 26 °C. Figure 3 reveals that during the south-west monsoon, the maximum temperature in this area will be constant in the range of 30 to 32°C then increases continuously during north-east monsoon season (February to March). The similar trend is expected from the year 2040-2099 and the degree is expected to achieve up to 37 °C (about 4 % more than the previous year).



Rainfall Pattern	J	F	M	A	M	J	J	A	S	O	N	D
South-West Monsoon												
North-East Monsoon												

Figure 3: The monthly temperature pattern for every interval year period

3.2 Rainfall Pattern

Figure 4 reveals that the amount of rainfall is expected to increase at several locations and estimated to focus on the middle area of Kedah such as Kota Setar, Pendang, Yan, Kuala Muda, Sik, and Baling district in the year of 2010 to 2039 (30years). The pattern of rainfall amount in average is expected to be not much different from the historical data. However, from November to December and February to April, the rainfall pattern is expected to increase due to the north-east monsoon season. The rainfall intensity is also estimated to increase from August to September, which is known as the primary monthly maximum. During these months, the amount of rainfall will reach 20 to 25 mm/day compared to normal condition, which is about 15 mm/day. However, at Kedah Peak, SM Gurun, and Ibu Bekalan Tupah, the rainfall is expected to reach up to 30 mm/day during critical months. This may be caused by the wind flow from the Malacca Straits. In average, the rainfall depth is expected to be 2644 mm/year. In year 2040-2069, the rainfall trend will be similar to the previous 30 years but the rainfall amount will differ at several locations. Based on the result, the amount of rainfall is expected to increase continuously at most of the locations with an average of 14 %, thus causing the total annual rainfall to rise up to 2944 mm/year. The increment will occur during north-east monsoon season, especially from February to April, August, November and December. However, a decrement is expected at Kedah Peak, Kota Sarang Semut, and Telok Chengai with an average of 8 %.

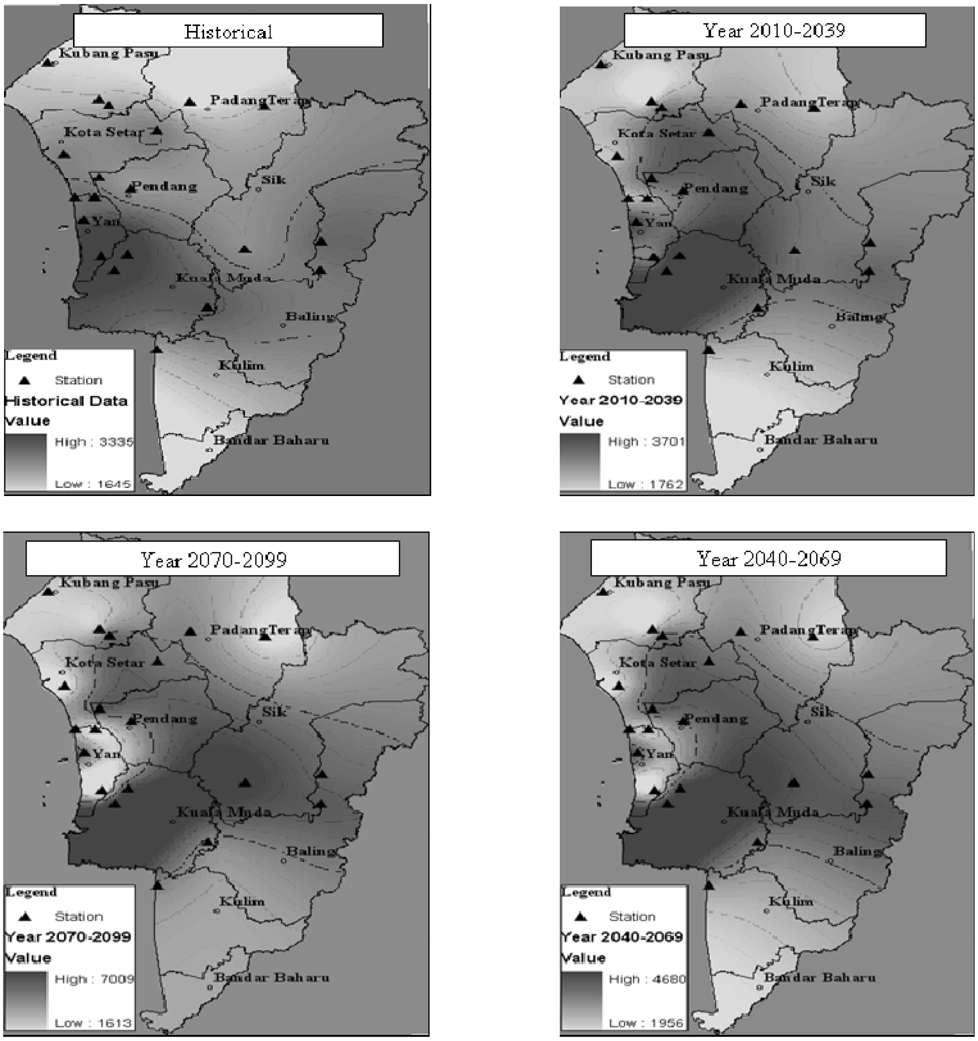


Figure 4: The total annual rainfall for every interval period

In year 2070-2099, the rainfall amount is expected to increase continuously and the annual rainfall is expected to reach 3717 mm/year. North-east monsoon season is the main contributor for the increment and more attention should be paid to prevent a disaster at that time. Ibu Bekalan Tupah will have the highest annual rainfall compared to other locations in Kedah. The mean monthly rainfall in this area is expected to achieve 65 mm/day in November, exceeding the historical 20 mm/day in the same month. Referring to the Meteorological Department Malaysia, the rainfall intensity is categorized into four groups, namely light (1-10 mm), moderate (11-30 mm), heavy (31-60 mm) and very heavy (more than 60 mm). In addition, flash flood is expected to occur if the convective rain falls more than 60 mm in two to four hours. However, other supported indices are required in measuring flood or drought at the catchment area such as stream flow, groundwater indices and at-site indices (Henny *et al.*, 2008).

3.3 Wet Spell Length

Wet spell length is a length of spells with amounts greater than or equal to the wet-day threshold (Wilby *et al.*, 2002) and wet day is defined as a day with at least 1 mm of rainfall. Figure 5 shows the frequency of rainy day starting from May to November and the peak time is from September to October (mostly 30 days) in year 2010-2099. Then, rainy day is expected to be lesser from January to March with only five to 20 rainy days. Nevertheless, based on the mean monthly rainfall intensity, it is expected that several locations in Kedah will receive higher rainfall intensity from February to March with an average of 16 mm/day from year 2010-2039. The rainfall amount is expected to increase continuously up to 33 mm/day and 200 mm/month in year 2070-2099. However, in October, the drizzling rain is expected to occur in the range of 8 to 17 mm/day in year 2070-2099. This result is supported by Cheang *et al.* (1986) in their study which stated that most of the rainfalls in Malaysia occur during short spells. Kedah Peak is expected to be the area with least rainy day, which is about 60 days a year, followed by Kodiang, which is around 80 days/year from 2070-2099. Kuala Nerang will have the most rainy days, which is about 275 days a year.

3.4 Dry Spell Length

Dry spell length is a contrast from the wet spell length and a day length is defined as a day with less than 0.1 mm of rainfall. Figure 6 shows the maximum dry spell at several locations that are expected to face higher dry length. Simulation result reveals that the longest dry spell length occurs at Kedah Peak, which is estimated to be within the range of 50 to 93 days a year from the year 2040-2099. This is an increase of about 270 % in average compared to the year 2010-2039 data, which showed only 20 days/year. The same circumstance is also expected in Kodiang where the longest period of dry spell in year 2040-2099 will increase up to 76 days a year but is nevertheless moderately lesser than the 20 days dry spell expected from year 2010-2039. Telok Chengai and Keretapi Tokai are predicted area that will produce higher dry spell with decreased length from year 2070-2099. Ladang Tanjung Pauh is estimated to have the shortest dry spell length within the range of one to 20 days in year 2040-2099

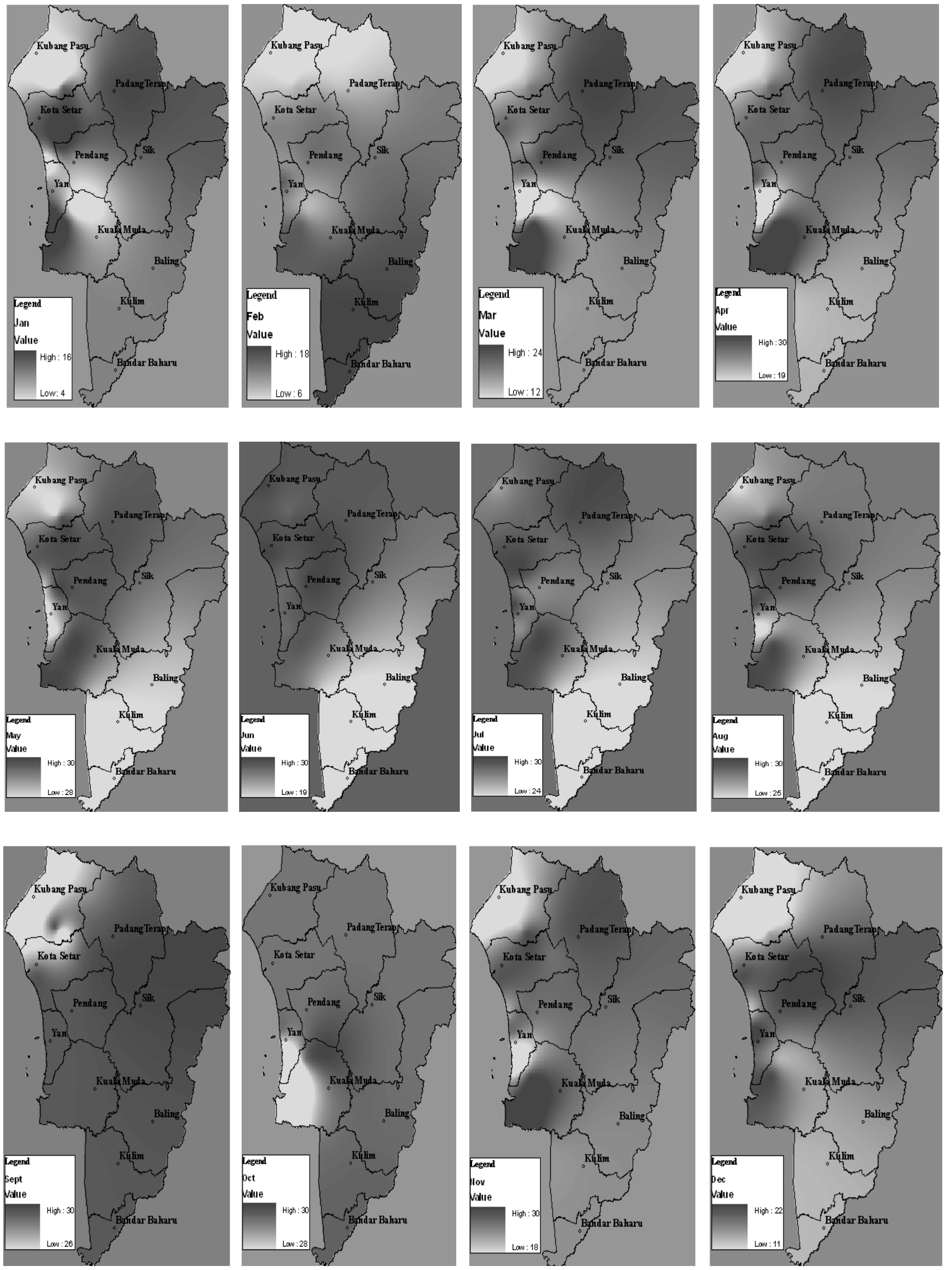


Figure 5: Spatial distribution of monthly wet spells in isohyets map (Year 2010-2039)

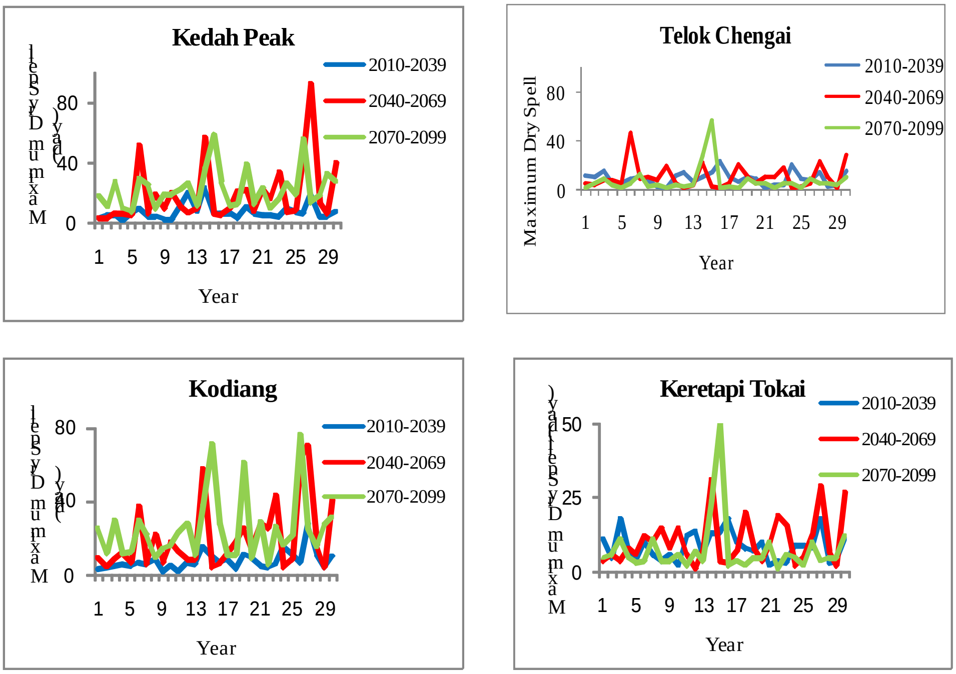


Figure 6: Maximum Annual Dry Length (day) at Expected Critical Station in Kedah

4.0 Conclusion

The climate trend assessment has been addressed, based on the temperature data of a recording station and rainfall record of 20 rainfall stations surrounding area in Kedah. There are three intervals period considered encompassed year 2010 to 2039, 2040-2069 and 2070-2099. The calibration was conducted on the 30years of historical data from year 1961 to 1990. During the simulation stage, it has been found that not much difference between the trend of the simulated and historical data for the temperature, total of rainfall amount, wet and dry spell length. But, the increment is expected to occur for every interval period. The higher amount of mean rainfall is expected to occur during south-west monsoon (August) and the higher temperature is expected during north-east monsoon (March). In contrast the impact on the rainfall pattern for the wet days and dry days can be seen quite significant for the north-east monsoon compared to the south-west monsoon. It has the considerable impact in rainfall pattern also known as wet season and dry season during south-west monsoon.

The simulation result reveals that the temperature is expected to increase with time as 3% in 2099. The temperature reading is expected moderate during the south-west monsoon and higher in north-east monsoon. The finding is considered reliable and the results of Meteorological Department Malaysia report confirmed the recent temperature at this area is 36.4^{o}C in Mac 2011 which is the highest monthly temperature in Malaysia.

The rainfall pattern is expected to increase in the middle area of state such as Kota Setar, Pendang, Yan, Kuala Muda, Sik, and Baling district and produce the similar trend in the future. The rainfall distribution is not uniform where several areas receive higher intensity as compared to the other areas. The heavy rainfall is expected to occur in November to December and February to April affected of north-east monsoon and also estimated an increase in August to September known as primary monthly maximum. Nevertheless, the locations those estimates having less intensity are Kubang Pasu, Padang Terap, Kulim and Bandar Baharu but the intensity is expected to increase for every interval period.

However, the wet spell length results reveal that the most of rainfall in Malaysia occurs in short spells (Cheang *et. al*., 1986). The phenomenon shows clearly during north-east monsoon (February to March) where only 5 to 20 rainy days during that time but the rainfall amount is an average 16mm/day in year 2010-2039 and increase continuously up to 33mm/day in year 2070-2099. The simulation of dry spell lengths reveals that the longest dry spell length occur at Kedah Peak and Kodiang in the range from 50 to 90 days/year while Ladang Tanjung Pauh is estimated the shortest dry spell length within the range of 1 to 20days in year 2040-2099.

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