

Identifying the Monotonic Trend in Climate Change Parameter in Kluang and Senai, Johor, Malaysia

(Mengenal Pasti Tren Berekanaanada di dalam Parameter Perubahan Iklim di Kluang dan Senai, Johor, Malaysia)

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ABSTRACT

Presently, climate change plays an important role as it gives a serious impact to the living things on earth. Analyzing the trend of climate change is very important in identifying the pattern of changes because it can give an initial overview for future analysis. In this study, trend analysis was carried out to study the pattern of changes for five climate change parameters, such as total amount of monthly precipitation (mm), monthly average temperature (°C), monthly average global radiation (MJm^{-2}), monthly average wind speed (m/s) and monthly average humidity (%) during the period of 1974 to 2010. Comparisons were made between two research stations, which were the Senai International Airport and Kluang Meteorological Stations. In this study, the Mann-Kendall trend test and Sen's slope estimator test were used to identify the monotonic trend for these climate change parameters. As a result of this analysis, the precipitations showed no trend for both locations and the radiation showed no trend in Kluang from both analyses. Meanwhile, other parameters in Senai and Kluang showed a monotonic trend, according to the Tau value (Z) and the Sen's slope value. The temperature shows a positive trend for both locations.

Keywords: Climate change parameter; Mann-Kendall trend test; monotonic trend; non-parametric trend estimator; Sen's slope estimator test

ABSTRAK

Perubahan iklim memainkan peranan yang penting pada masa kini berikutan kesan serius terhadap kehidupan di bumi. Analisis tren perubahan iklim amat penting dalam mengenal pasti perubahan coraknya kerana analisis ini dapat memberi gambaran awal dalam membuat analisis lanjutan. Dalam kajian ini, analisis tren dilakukan untuk melihat perubahan iklim bagi parameter perubahan iklim, iaitu jumlah jatuhan hujan bulanan (mm), purata suhu bulanan (°C), purata radiasi global bulanan (MJm^{-2}), purata kelajuan angin bulanan (m/s) serta purata kelembapan bulanan (%) sepanjang tempoh 1974 sehingga 2010. Perbandingan dibuat antara dua stesen kajian, iaitu stesen meteorologi Lapangan Terbang Antarabangsa Senai dan Stesen Meteorologi Kluang. Dalam kajian ini, ujian tren Mann-Kendall dan ujian anggaran kecerunan Sen digunakan bagi melihat tren parameter perubahan iklim. Keputusan daripada analisis ini menunjukkan tiada tren parameter hujan bagi kedua-dua kawasan dan radiasi juga tidak menunjukkan tren keputusan daripada kedua-dua analisis. Manakala parameter lain menunjukkan tren berekanada di Senai dan Kluang berdasarkan nilai Tau (Z) dan nilai kecerunan Sen. Tren positif ditunjukkan bagi suhu di kedua-dua kawasan.

Kata kunci: Anggaran tren tak berparameter; parameter perubahan iklim; tren berekanada; ujian anggaran kecerunan Sen; ujian tren Mann-Kendall

INTRODUCTION

Knowledge in the field of meteorology is important because it will affect both human life and the development of the country. Over the years, climate change has become a major topic of discussion (Pin et al. 2013). The analysis of climate change has increasingly attracted the attention of many researchers due to their concerns over the impact of climate change on human and environment in the present and the future. It may cause major changes in climatic variables such as precipitation (Heim 2015) air temperature (Fonseca et al. 2016), relative humidity and solar radiation (Haskett et al. 2000). Climate change is one of the most serious challenges faced by humanity in the 21st century (Vo et al. 2015) where it gives a serious impact to human

health, natural ecosystems, agriculture, water resources (Ikhwanuddin et al. 2016), occurrence of harmful algae in water (Soon & Ransangan 2016), energy consumption, transport (Jarvis et al. 2008), increase of temperature of the region (Bachelet et al. 2016), increase of the hydrological cycle (Apurv et al. 2015), effects on landslide activity (Rianna et al. 2014) and energy consumption (Shibuya & Croxford 2016). Chandler and Scott (2011) claimed that investigating the trend of climate change parameter is important to understand the climatology history for future predictive.

In Malaysia, floods and flash floods occur in tradition, especially in the east coast areas during the monsoon season (Gasim et al. 2010). However, the recent severe

flooding that occurred in Johor is the result of a new weather phenomenon caused by heavy rain brought by winds from the South China Sea and the western Pacific Ocean (The Star 2006). Typhoon Utor is the main factor leading to the severe floods in Johor and Malaysia in 2006 and 2007 (Amirullah 2011). According to the Federal Department of Town and Country Planning Peninsular Malaysia (2011), typhoon Utor was said to be the main source of this extraordinary rain, where it caused rainfall drops to be above the usual level, which is 350 mm within 24 h. Eventually, the water level will rise immediately cause major floods in these locations.

According to the report presented by the Malaysian Meteorological Department (2014), there are some obvious effects of climate change such as an increase in average annual temperature in Peninsular Malaysia by 0.02°C , which is equivalent to 2°C per 100 years. Additionally, a report from the National Hydraulic Research Institute of Malaysia (NAHRIM) showed there has been an increasing amount of rainfall since 2000 by 17% as compared to 1970 (Shaaban 2013). This is one example of the rapid effects of climate change in Malaysia.

Therefore, understanding the trends and future trends of climate change parameters would help researchers or meteorologists produce better planning in dealing with the climate change phenomenon. The techniques of trend detection has attracted the attention and interest of researchers over the decades (Jamaludin et al. 2010), particularly in the studies of climate change such as temperature and precipitation (Anghileri et al. 2014; Onyutha et al. 2015; Rosmann et al. 2016). They have also proposed to use sophisticated methods such as parametric models (deterministic trend), non-parametric estimated trend and stochastic trend in order to avoid any confusion when concluding the trend analysis.

In a nutshell, the objective of this research was to utilize the Mann-Kendall trend test to investigate the monotonic trend in the climate change parameter, while Sen's slope estimator was used to estimate the changes of the climate change parameter by comparing the result with the Mann-Kendall trend test. A comparison was made between the Mann-Kendall trend test and Sen's slope estimator as the Mann-Kendall statistical test has been frequently used to quantify the significance of trends in hydro-meteorological time series (Mondal et al. 2012; Yue et al. 2002). While Sen's slope estimator has been widely used in hydro-meteorological time series (Tabari et al. 2011). The climate change parameters used in this study were the total amount of monthly precipitation (mm), monthly average temperature ($^{\circ}\text{C}$), monthly average of global radiation (MJm^{-2}), monthly average wind speed (m/s) and monthly average humidity (%) during the period of 1974 to 2010. A comprehensive analysis among the climate parameters was performed in this study. The changes in the monotonic trend have been carried out in the results that were obtained from each method for both stations. This research work has never been seen before for the locations and the parameters used in this study.

MATERIALS AND METHODS

Climate change parameters such as total amount of monthly precipitation (mm), monthly average temperature ($^{\circ}\text{C}$), monthly average of global radiation (MJm^{-2}), monthly average wind speed (m/s) and monthly average humidity (%) were considered in this research. There are also other climate change parameters that can be used in order to investigate the trend of the climate change parameters. Willett et al. (2007) used atmospheric water vapor and Tao et al. (2011) used vapor pressure, sunshine duration and potential evaporation as additions to the basic climate change parameter in order to investigate the trend of the climate change parameters. However, only five climate change parameters were considered in this study because most of the studies in recent years have focused on changes in temperature, precipitation (Gocic & Trajkovic 2013), humidity (Singh et al. 2008), wind speed (Jiang et al. 2010) and radiation (Trabea & Shaltout 2000) only. Besides that, the use of climate change parameters in this study is because it is related to the climate change studies and also because it depends on the availability of the long term historical data provided by the Malaysian Meteorological Department.

The monthly time series data for the parameters of climate change during the years of 1974-2010 was used for analysis due to the availability of data. Comparisons were made among two research stations. First, Senai International Airport ($01^{\circ}38'\text{N}$, $03^{\circ}40'\text{E}$) and second, Kluang meteorological station ($02^{\circ}01'\text{N}$, $103^{\circ}19'\text{E}$). Kluang and Senai are located in the north and center of Johor Bahru, respectively. The selection of these two areas is based on the history of heavy rains that hit both areas in the south of Peninsular Malaysia at the end of 2006. In addition, Senai and Kluang recorded the highest amount of rainfall during the heavy rainy seasons, which are 264 and 171 mm and the highest number of flood victims recorded was 5,645 in Senai and 5,433 in Kluang. Besides that, the selection of the locations is to compare whether they have the same monotonic trend in both locations during the period of the study based on the historical data. This is because, both locations are located at the south of Peninsular Malaysia and had experienced being hit by the heavy rainfall in 2006. Statistical analyses were performed using the R Programming package (version 3.2.5).

MANN-KENDALL TREND TEST

In this study, the Mann-Kendall trend test was used to see whether there is a monotonic trend in climate change parameters. The Mann-Kendall trend test is a non-parameteric statistical test that is widely used for the analysis of climate trend variables (Mezdour & Probst 2016; Zhao et al. 2015) and also in the analysis of time series (Pingale et al. 2014). The non-parametric Mann-Kendall statistical method was the main approach employed since it is very useful in hydro-meteorological studies (Altin & Barak 2014; Araghi et al. 2016). The

reason for using the non-parametric statistical tests is because, as compared to parametric statistical tests, non-parametric tests were considered more appropriate for data that is not normally distributed and also for filtered data, which is often encountered in hydro-meteorological time series data (Yue & Pilon 2004; Yue et al. 2002). There are two advantages in using the Mann-Kendall trend. First, it is a non-parametric test and does not require the data to be normally distributed (Karmeshu 2012). Second, this test has a low sensitivity to break significantly due to the non-homogeneous time series (Tabari et al. 2011).

The null hypothesis H_0 for the Mann-Kendall trend test assumes that there is no trend (data independent and random) and it is tested against the alternative hypothesis H_1 , which assumes the data contains trend (Bihrat & Mehmet 2003). Probability value (p-value) is used for the hypothesis testing. If the p-value showed a number greater than $\alpha = 0.05$, thus, it has failed to reject the null hypothesis and it can be concluded that there is no trend; and if the p-value is lower than $\alpha = 0.05$, H_0 will be rejected, which means there is a statistically significant trend in the series (Tian 2016). Based on Kendall (1975) and Mann (1945), the calculation for the Mann-Kendall statistical tests is as follows:

$$T_{MK} = \frac{S - \text{sgn}(S)}{\sqrt{V(S)}} \quad (1)$$

$$s = \sum_{i=1}^{n-1} \sum_{j=i+1}^n \text{sgn}(x_j - x_i),$$

where n is the number of data points; x_j and x_i are the data value in time series; i and j ($j > i$) is the total dataset; and $\text{sgn}(x_j - x_i)$ is the sign function, whereby they are calculated as follows:

$$\text{sgn}(x_j - x_i) = \begin{cases} +1, & \text{if } (x_j - x_i) > 0 \\ 0, & \text{if } (x_j - x_i) = 0 \\ -1, & \text{if } (x_j - x_i) < 0 \end{cases} \quad (2)$$

The variance is calculated as:

$$E(S) = 0 \quad (3)$$

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{k=1}^m t_k(t_k-1)(2t_k+5)}{18}, \quad (4)$$

where t_k is the total bonding point k . Standard statistical test z is calculated as,

$$z_s = \begin{cases} \frac{S-1}{\sqrt{V(S)}}, & \text{if } S > 0 \\ 0, & \text{if } S = 0 \\ \frac{S+1}{\sqrt{V(S)}}, & \text{if } S < 0 \end{cases} \quad (5)$$

and standard statistical Mann-Kendall z is the standard normal distribution with a mean of zero and a variance of one. A positive value (negative) z showed an increase (decrease) trend (Mozejko 2012). H_0 is rejected if the value $|Z_s|$ is greater than the value $z_{\alpha/2}$, in which α represents the selected level of significance and so the null hypothesis is not valid with the understanding that there is a significant trend (Motiee & McBean 2009).

SEN'S SLOPE ESTIMATOR TEST

If a linear trend is present in a time series, then the true slope (change per unit time) can be estimated by using a simple non-parametric procedure. Sen (1968) developed the non-parametric procedure for estimating the slope of trend in the sample of N pairs of data. The Sen's slope estimator test has been used in this research to estimate the changes for all the climate change parameters. The Sen's slope estimator test is a non-parametric method to estimate the slope of trend in the sample of N pairs of data. Where,

$$Q_i = \frac{x_j - x_k}{j - k} \quad \text{for } i = 1, \dots, N, \quad (6)$$

x_j and x_k are the data values at times j and k ($j > k$), respectively. If it only has one observation in each time period, then

$$N = \frac{n(n-1)}{2}, \quad (7)$$

where n is the number of time periods; and if there are multiple observations in one or more time periods, then

$$N < \frac{n(n-1)}{2}, \quad (8)$$

where n is the total number of observations. The median of slope or Sen's slope estimator is computed as,

$$Q_{med} = \begin{cases} Q_{[(N+1)/2]} & \text{if } N \text{ is odd} \\ \frac{Q_{[N/2]} + Q_{[(N+2)/2]}}{2}, & \text{if } N \text{ is even} \end{cases} \quad (9)$$

If the Q_{med} gives a positive value, it indicates an upward or increasing trend, while a negative value indicates a downward or decreasing trend.

RESULTS AND DISCUSSION

The statistical analysis of the parameters of climate change in Senai and Kluang from 1974 until 2010 is shown in Tables 1 and 2. From the analysis, it can be seen that the mean of the monthly average temperature in Senai is 27.49°C and in Kluang is 27.73°C. The mean of monthly average temperature between these two locations is almost the same throughout the 38 years. While for standard deviation, it gives a small value, giving an assumption that the data points are close to the mean value. Malaysia receives heavy rainfall between 2000 and 3000 mm per

TABLE 1. Statistical analysis of parameters of climate change in Senai

Parameter	Mean	Standard deviation	Minimum	Maximum	Range
Temperature (°C)	27.49	0.69	24.5	30.1	5.6
Precipitation (mm)	204.2	107.16	7.9	907.2	899.3
Wind (m/s)	2.7	0.7	1	4.9	3.9
Radiation (MJm ⁻²)	14.61	2	7.43	20.94	13.51
Humidity (%)	86.38	2.45	77	92	22

TABLE 2. Statistical analysis of parameters of climate change in Kluang

Parameter	Mean	Standard deviation	Minimum	Maximum	Range
Temperature (°C)	27.73	0.76	25.59	29.75	4.16
Precipitation (mm)	176.5	107.69	4.8	775.6	770.8
Wind (m/s)	2.1	0.9	0.6	5.2	4.6
Radiation (MJm ⁻²)	15.87	1.64	9.9	21.4	11.5
Humidity (%)	85.98	3.09	76	99	23

year. According to this analysis, the mean for precipitation in Senai is 204.2 mm while for Kluang is 176.5 mm. However, the total amount of monthly rainfall is very high. The maximum precipitation recorded in Senai is 907.2 mm and in Kluang is 775.6 mm. Eventually, it gives a high value for the standard deviation for both locations, which is 107.16 mm for Senai and 107.69 mm for Kluang. This is not surprising since Senai and Kluang have severe flood incidents in 2006 and it gives a high value for the standard deviation as compared to other parameters. By referring to the parameter of wind speed, the mean for the monthly average wind speed in both locations is quite low. This is true according to the Malaysian Meteorological Department (2014), who claimed that the wind speed in Malaysia is low and keeps changing directions. The gap between the minimum and the maximum values of wind speed is not too big and it has resulted in a low value for the standard deviation.

The maximum number for the average monthly radiation in Senai and Kluang is 20.94 MJm⁻² and 21.4 MJm⁻², respectively. It can be said that radiation in these two locations is still in the normal range. Normally, the amount of global radiation is from 1 MJm⁻² to 35 MJm⁻². The amount is higher during sunny days and lower during cloudy and rainy days. While for humidity, Senai and Kluang received a high relative humidity, where the maximum number of

average monthly relative humidity in these two locations is 92% for Senai and 99% for Kluang. Malaysia normally receives a high relative humidity of not more than 80% (Malaysian Meteorological Department 2017).

The results of the Mann-Kendall trend test and Sen's slope estimator test for Kluang and Senai can be seen in Tables 3 and 4. From Table 3, it can be seen that precipitation is the only parameter that indicated no significant trend in Senai. Meanwhile, other parameters indicated a monotonic trend. The same goes to Kluang, whereby the precipitation indicated no significant trend, while the radiation indicated no trend only from Sen's slope estimator. However, other parameters have a trend according to both results. If we refer to the Tau value (Z), both locations show an increasing trend for the temperature when the Tau value (Z) gives a positive value, which are 0.236 and 0.354. While for the Sen's slope estimator test, it gives a value of 0.149 and 0.0201. Meanwhile, for wind speed and humidity, both locations show a decreasing trend when it gives a negative Tau value (Z) and negative Sen's slope value. For radiation in Senai, it shows a decreasing trend based on the Tau value (Z) and Sen's slope value. However, the radiation in Kluang shows no trend when it gives a p-value of 0.765 and 0.6943.

According to the results, it can be depicted that some of the parameters show a monotonic trend, while some do not

TABLE 3. Significant test results for Senai

Parameter	Mann-Kendall trend test			Sen's slope		
	Tau value, Z	p-value	Test conclusion	Sen's value	p-value	Test conclusion
Temperature (°C)	0.236	2.22e-16	Monotonic trend	0.149	2.98e-06	Monotonic trend
Precipitation (mm)	0.061	0.06	No trend	0.052	0.1052	No trend
Wind (m/s)	-0.308	2.22e-16	Monotonic trend	-0.202	-2.45e-10	Monotonic trend
Radiation)	-0.273	2.93e-10	Monotonic trend	-0.169	-0.0001	Monotonic trend
Humidity (%)	-0.252	5.73e-14	Monotonic trend	-0.179	-2.19e-08	Monotonic trend

TABLE 4. Significant test results for Kluang

Parameter	Mann-Kendall trend test			Sen's slope		
	Tau value, Z	p-value	Test conclusion	Sen's value	p-value	Test conclusion
Temperature (°C)	0.354	2.22e-16	Monotonic trend	0.201	0.0001	Monotonic trend
Precipitation (mm)	0.055	0.0819	No trend	0.046	0.1511	No trend
Wind (m/s)	-0.553	2.22e-16	Monotonic trend	-0.352	-0.0001	Monotonic trend
Radiation)	0.0152	0.765	No trend	0.019	0.6943	No trend
Humidity (%)	-0.18	6.68e-08	Monotonic trend	-0.119	-0.0002	Monotonic trend

have a monotonic trend. Investigating the trend of climate change parameters is very important as early detection for future analysis and forecasting of climate change have become so important to global issues, especially in global warming, green house issues and ozone depletion. The knowledge of how and where the climate has varied and is changing is crucial in developing successful coping strategies for agriculture and eco-systems in general (Heim 2015). When the result shows any significant monotonic trend for the climate change parameters, it can give a big insight to the researcher in order to determine and make an early judgement about the climate change in Malaysia. However, if the parameters do not show any monotonic trend, future investigation is needed in order to know the overall general trend for the parameters through the years. Early detection is crucial as it can give little information about the parameters and how far it can affect the climate change in future.

Arising from the result, the temperature shows a positive trend throughout the years for both locations. According to Yunling and Yiping (2005), they had indicated that temperature has increased from 1960 to 2000 at 19 stations along the Lancang River (China). Meanwhile, Ceppi et al. (2012) showed that temperature has increased in Switzerland from 1959 to 2008. A study in Malaysia by Hashim (2010) had shown that there is an increasing trend for temperature from 1970 to 2005 in the urban areas. As reported by the Director of the Malaysian Meteorological Department in the local newspaper Sinar Harian (2013), he confirmed that the increase in of temperature might be due to the Southwest Monsoon, which usually brings hot and dry weather conditions. In addition, the temperature and heat have increased with the advent of the tropical storm in the Philippines and low pressure from the Indian Ocean.

However, wind and humidity show a negative trend for both locations. Satari et al. (2015) mentioned in their study that meteorological conditions such as wind are very much dominated by the monsoon season. A study on wind speed trend had been done by Jiang et al. (2010) in China from 1956 to 2004 and they concluded that they all showed decreasing trends over broad areas of China. While for radiation, a negative trend was found only for Senai. However, no trend is recorded for radiation in Kluang. Despite such interesting results, it has a different conclusion as compared to other parameters in both locations. A study conducted by Liu and Scott (2001)

mentioned that radiation is influenced by temperature and frequency of rainfall. In this study, the varying results for radiation in both locations might be due to temperature and precipitation. Since this study is focused on the trend, it is recommended to investigate the correlation between radiation with other climate change parameters for future research.

CONCLUSION

This research is pertaining to the trends analysis for climate change parameters in the Senai and Kluang areas. Understanding of the climate change trend is an important requirement for planning and management, especially for water resources, construction projects and plantation issues. From this study, it gives some insight about the trend pattern in climate change parameters in both locations. The parameters are temperature, precipitation, wind speed, global radiation and relative humidity. With this little effort of research, it might give some contribution in understanding the trend of climate change variables.

A statistical analysis was made as a first step in understanding the data. The Mann-Kendall trend test is a suitable technique to be used since it is one of the techniques that are widely used for environmental and climate studies. However, the Sen's slope estimator test has also been used in this research to estimate the trend for all the climate change parameters and it gives a good result like the Mann-Kendall trend test result. There is not much gap difference from the results shown in both methods. The Sen's slope estimator test gave a lower estimated value as compared to the Mann-Kendall trend test. Overall, the results of the Mann-Kendall trend test and Sen's slope estimator test gave a good result in the detection of the trend for climate change parameters. Both methods can be used in predicting and estimating a trend especially for climate change parameters.

In conclusion, the findings from this study may give useful information regarding the trend of climate change parameters in Senai and Kluang. Additionally, this trend analysis can be extended for further analysis, such as in identifying significant correlations among the climate change parameter as some of the parameters give different results in both locations such as radiation. Besides that, the analysis of monthly trends for each parameter can also be considered for future analysis.

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