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CLIMATE CHANGE DETECTION IN FOUR LOCATIONS IN PENINSULAR MALAYSIA FOR GREEN SUSTAINABILITY AWARENESS

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ABSTRACT

Climate change impacts ecosystems, often resulting in the extinction of many species and their habitats and harm to human health. Preserving and protecting green spaces is essential to maintaining ecosystem health. This study aims to detect and examine climate change and its impact on temperature and rainfall at four locations in Malaysia to increase green environment sustainability awareness. The methodology involved investigating the pattern of climate variation using several visualization tools, the Mann-Kendall test, the EWMA control chart, and the Kruskall-Wallis test. Data on monthly average temperature and rainfall amount for the 30 years between 1989 and 2018 was obtained from the Department of Meteorology in Petaling Jaya. The study locations are Ipoh in Perak, Kuala Krai in Kelantan, Mersing in Johor, and Temerloh in Pahang, Peninsular Malaysia. To evaluate climate change, the 30 years of monthly data are divided into three cohorts: Cohort 1 (1989-1998), Cohort 2 (1999-2008), and Cohort 3 (2009-2018). The analysis confirms that climate change is evident across all four study locations. Mersing exhibited the highest rate of change in mean temperature, with an increase of 0.94% in Cohort 2 and 2.45% in Cohort 3 compared to Cohort 1. Meanwhile, Ipoh recorded the greatest rate of change in mean rainfall, with an increase of 20.62% in Cohort 2 and 19.91% in Cohort 3, compared to Cohort 1. The study findings support the need for green environment awareness among all Malaysians and an increased effort to educate and implement the love for nature in the general public so that our green environment can be sustained.

Keywords: *Climate Change, Control Chart, Malaysia Environment, Rainfall, Temperature*

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1. Introduction

Climate change refers to a systematic or significant change in the long-term statistics of climate variables, normally described in terms of information such as average temperature, rainfall, precipitation, or wind. Climate change results from both natural variations and human activities, with increasing greenhouse gas concentrations being a primary driver (Pin, Pereira, & Aziz, 2013; Mikhaylove et al., 2020). Althor, Watson and Fuller (2016) highlights the impact of anthropogenic climate change whereby all countries globally emit greenhouse gases to increase lifestyle and economic growth. The rise in global temperature is largely attributed to greenhouse gases produced by human activities. Heavy industrial activities have been on a trend and are seen to lead to the accumulation of industrial gases. The effects of global warming can already be a hot issue in the environment lately, such as intense heat waves, melting of sea ice, wildlife populations, and habitats shifting due to the extreme weather (Kamati et al., 2024). The Intergovernmental Panel on Climate Change (IPCC) report in the year 2018 concluded that there is more than a 95 percent probability that human-produced greenhouse gases such as Carbon Dioxide, Methane, and Nitrous Oxide have caused the increase in Earth's temperatures over the past 50 years (Masson-Delmotte et al., 2018). Increasing greenhouse gases contribute to environmental issues such as air pollution, extreme weather events, flooding, and climate degradation (Althor, Watson & Fuller, 2016; Baba-Adamu & Ibrahim, 2021; Redzuan et al, 2023). The gases that contribute to the greenhouse effect include water vapor, Carbon Dioxide (CO2), methane, Nitrous Oxide, and chlorofluorocarbons (CFCs). Extreme rainfall is also seen as an impact of climate change (Noor et al., 2023).

Several investigations on climate changes in the Malaysian environment have been conducted previously. For example, recent research by Ibrahim et al., (2024) investigated the impact of climate change on the solar system in Malaysia. Another study by Firdaus et al., (2020) found that climate change poses a severe threat to paddy production. A previous study by Tan et al., (2019) has also proven that there is a warming trend in the Muda River Basin in Peninsular Malaysia, where, in detail, the number of cold days and nights is decreasing while the number of warm days and nights is increasing in Southeast Asia. Tan et al., (2019) also found out that the results were due to the agricultural land expansion and logging activities in that area. Suhaila (2015) stated that from her findings, the majority of the stations that have been analyzed had experienced a statistically significant increasing trend, while Subang station is recorded as the largest estimated trend. A study by Suhaila and Yusop (2018) found that there is a significant increasing trend in the annual and seasonal mean, maximum, and minimum temperatures in Peninsular Malaysia from 1980 to 2011 and that the local mean temperatures also have increased in the range between 2°C and 5°C per 100 years. Other than that, another research, by Wong, Yusop and Ismail (2018), showed that at a 95% confidence level, there is a significant increasing trend of mean temperature with 0.32°C per decade in Malaysia.

Kaur (2019) also stated that in February 2019, Malaysia was alarmed at Level 1 after ten areas experienced a temperature of between 35 degrees Celsius and 37 degrees Celsius and the areas involved were Chuping in Perlis; Kubang Pasu, Kota Setar, Sik in Kedah; Kepong in Kuala Lumpur; Hulu Perak, Kuala Kangsar, Kinta in Perak; Maran in Pahang; and Tangkak in Johor. Due to the dry weather, there were many cases where people suffered from heatstroke, dizziness, difficulty breathing, vomiting, fainting, muscle cramps, and many more. This will affect the society's health and the quality of the environment. Thus, there is a need for awareness of improving the lifestyle of human beings and efficient management of industrial and manufacturing companies so that the emission of greenhouse gases can be controlled and the green environment can be sustained for the next generation. Investigating climate change in the Malaysian environment is important for understanding, addressing, and mitigating its impact.

This study aims to investigate the existence of climate change in the Malaysian environment. As an alternative to the common visualization approach, this study proposes adopting a well-known manufacturing statistical process control (SPC) tool, the EWMA control chart, into the application in the environmental data. The study also employed the Mann-Kendall Trend test and the Kruskall-Wallis test in the analysis to test the changes. The study findings could provide the evidence needed to inform policy decisions, protect communities, preserve ecosystems, and build a sustainable future for generations.

2. Methodology and Methods

This topic section discusses the research methodology, the materials and methods used in this study to achieve the research objective. It is a quantitative exploratory study.

2.1 Data and Sources

This study utilized secondary historical data on monthly average temperature and rainfall from 1989 to 2018, comprising 360 data points. The data were obtained from the Department of Meteorology in Petaling Jaya involving four locations in Peninsular Malaysia: Ipoh in Perak, Kuala Krai in Kelantan, Temerloh in Pahang, and Mersing in Johor. The study locations are depicted in Figure 1 (i.e., the highlighted locations in the box).

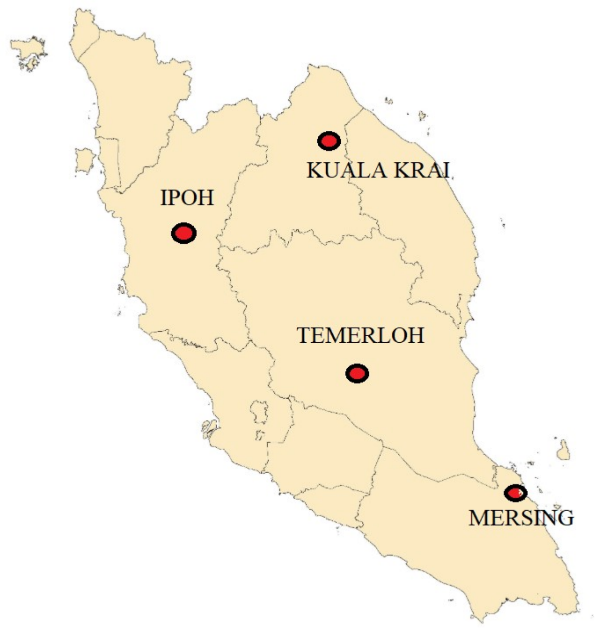


Figure 1 Maps of the study locations.

Apart from data availability and time constraints for research, these locations were selected for this study due to their frequent occurrence of high-temperature records (Ahmad, 2018). Since data analysis requires complete historical data, due to a small missing percentage (<1%), the missing values were replaced with the average value (Acuna & Rodriguez, 2004). The significance of replacement is to prevent discontinuity of time series data for control chart analysis. The clean data set will then be divided into three cohort years data sets. This is done to compare and detect any changes or differences among the three cohort years. Table 1 illustrates the partitioning of the years into three main cohorts: Cohort 1 (Year 1989-1998), Cohort 2 (Year 1999-2008), and Cohort 3 (Year 2009 – 2018).

Table 1. Variables and Data Description

Variables	Temperature - Monthly Temperature (°C) Rainfall - Amount of rainfall (mm)		
Cohort	**Years**	**Number of Years**	**Total Points (Monthly)**
1	1989 - 1998	10 years	120 points
2	1999 – 2008	10 years	120 points
3	2009 - 2018	10 years	120 points

2.2 Exponentially Weighted Moving Average (EWMA) Control Chart

EWMA control chart is a time-weighted control chart and may be used to detect small process shifts. In the EWMA control chart, the weighting factor considers all previous points that resulted in an outcome that is more influenced by recent points. It is also flexible and resistant to data autocorrelation, thus making it more robust and efficient. The EWMA control chart was introduced by Roberts in 1959. The chart consists of a center line (CL) and two limit lines, the lower control line (LCL) and the upper control line (UCL). The development of the chart depends on statistic Z_i. The researcher plots the computed Z_i values for assessment and monitoring a production process system, whether the process is in control or out of control (Febrina & Fitriana, 2022). If the plotted points of statistic Z_i lie between the LCL and UCL, as well as if the points exhibit a particular pattern even within the two-line limits, it indicates that the process is in control. The statistics Z_i can be written as in Eqn (1).

$$z_i = \lambda x_i + (1-\lambda)z_{i-1} \tag{1}$$

The parameter λ, where $0 < \lambda \leq 1$, is a constant, and the starting value is the process target, so that $z_0 = \mu_0$. It acts as a smoothing factor, dictating the relative importance of the current observation versus previous ones. In other words, it controls the stability of the control chart due to short-term fluctuation. Based on the common practice, the value of λ used in this study is 1.5 (Li et al., 2021).

The center line, upper, and lower control limits for the EWMA control chart are written as follows:

$$\text{UCL} = \mu_0 + L\sigma\sqrt{\frac{\lambda}{(2-\lambda)}[1-(1-\lambda)^{2i}]} \tag{2}$$

$$\text{Center line} = \mu_0 \tag{3}$$

$$\text{LCL} = \mu_0 - L\sigma\sqrt{\frac{\lambda}{(2-\lambda)}[1-(1-\lambda)^{2i}]} \tag{4}$$

Practically, the establishment of the EWMA chart needs to go through two phases: Phase 1 and Phase 2. The purpose of Phase 1 is to use the control chart to experiment iteratively in finding a data set that represents an in-control process system. These data are referred to as norm process data representing day-to-day variation data levels. This study will use the Phase 1 control chart analysis results to detect climate change by examining the shifting in the mean (i.e., CL line) of the control chart for the variables temperature and rainfall from decades to decades (Cohort 1,2, and 3). A Phase 2 control chart is used for monitoring future changes or variations of rainfall and temperature to spot any violation of a normal process system that also exhibits the existence of assignable causes. The CL, LCL, and UCL of the Phase 2 control chart are obtained based on the results of the control limits of Phase 1. This study used the normal data set resulting from the Phase 1 control chart analysis to assess the mean shifting effect of climate change on temperature and rainfall amount. The climate change effect on temperature and rainfall data is measured based on the final center line (CL) value estimated in the Phase I analysis. This CL value represents the normal average level in the environment during a particular time cohort. Thus, the rate of change can be measured by calculating the percentage of the difference in the UCL value between the current time frame (Cohort 2 and 3) with the base time frame (Cohort 1).

2.3 Mann-Kendall Test

Trends in a time series of data can be found using the non-parametric statistical test known as the Mann-Kendall test. It is frequently used in economics, hydrology, climatology, and environmental research to determine if a dataset shows a rising or falling trend over time without presuming that the data follows a particular distribution. This method is flexible because it is a non-parametric method that does not require any statistical assumptions. Mann-Kendall test finds monotonic tendencies in the data, which are either continuously increasing or decreasing. It assigns ranks by comparing the relative magnitudes of data point pairs. These comparisons provide the basis of the test statistic (Gumus et al., 2022). Sen's slope estimator is another statistical method used to analyze trends, but it focuses primarily on determining the magnitude of the trend. The relationship between the two statistics is that the Mann-Kendall test is used to assess whether a trend exists, and if a significant trend is identified, Sen's slope can then be applied to estimate its rate. In this study, the emphasis is on applying the Mann-Kendall test.

The Mann-Kendall statistic (denoted as S) is computed by summing the differences for all pairs of values, weighted by the sign of the difference:

$$S = \sum_{i<j} sign(x_j - x_i) \quad (5)$$

where sign (x_i-x_j) is 1 for an upward trend, -1 for a downward trend and 0 for no trend. The test statistic *S* is used to calculate the variance S under the assumption of no trend. For large sample sizes, the statistics follow a normal distribution, and the significance of the trend can be tested using a Z-score:

$$Z = \frac{S}{\sqrt{Var(S)}} \quad (6)$$

where Var(S) is the variance of the statistic. The Z-score can be used to determine whether a statistically significant trend exists. If the Z-score is large and positive, it indicates a significant upward (increasing) trend; if the Z-score is large and negative, it indicates a significant downward (decreasing) trend; and if the Z-score is close to zero, it indicates no significant trend.

2.4 Examining Climate Change Effect Using the Kruskal-Wallis Test

Through this process, the patterns of variation in each control chart are observed to identify which locations give the most changes in the process. The Kruskal-Wallis test does not have to make any assumptions on data normality compared to the ANOVA test. Kruskal-Wallis also known as a non-parametric test. The method is more flexible as it is appropriate due to its distribution-free data application (Ostertagova, 2014). This test is used to determine whether there are any significant differences in the median of temperature and rainfall amount among the three cohorts year. The median is used as a measure to data average. The hypotheses for the test are as follows:

$$H_0 = \widetilde{x_1} = \widetilde{x_2} = \widetilde{x_3} \quad (7)$$

$$H_1 = At\ least\ one\ median\ is\ not\ equal \quad (8)$$

The null hypothesis states that the populations from which the samples are drawn have the same median, while at least one population has a different median for the alternative hypothesis. The decision to reject or accept the null hypothesis is based on the statistics. The procedure - The analysis involved the computation of statistics:

$$H = \frac{12}{N(N=1)} \sum \frac{R_j^2}{n_j} - 3(N+1) \quad (9)$$

Where N is the total size for all observations, R is the sum of the ranks for j=1,2,3 groups or population to compare an n is the samples from each group j.

The step-by-step hypothesis testing procedure for the Kruskal-Wallis test is as follows:

Step 1: Set up the null and alternative hypothesis
Step 2: Set the significance level
Step 3: Combine all data from groups and rank them from the smallest to the largest. If there are tied values, assign them the average of the ranks. For each group, calculate the sum of the ranks for the observations in that group (R_j).
Step 3: Compute the test statistics H and the p-value
Step 4: Compare the p-value with the significance level. If p-value < the significance level, reject the null hypothesis.
Step 5: Conclude.

In this study, the Kruskal-Wallis test determines whether the average of two or more groups of cohorts is different. The results will tell whether there is any significant difference in the average temperature or rainfall levels between the three cohorts. The p-value of 0.05 will be the indicator to show the significance of the value. When the p-value is less than or equal to 0.05, it will indicate a significant difference among the averages; meanwhile, if the p-value is more than 0.05, the differences among the averages are not statistically significant.

3. Results and Discussions

3.1 Trend Analysis

Trend analysis of meteorological data can help identify climate change effects. This can be seen via a significant long-term trend pattern (annual or seasonal averages). One of the clearest indicators of climate change is the increase in global temperatures and extreme precipitation (Li et al., 2019). The Mann-Kendall test results for every sample station throughout the 30 years from 1989 and 2018 for temperature and rainfall amount are presented in Table 2 and Table 3, respectively.

Table 2 Mann-Kendall Trend Test of Mean Temperature

Station	Mann-Kendall test trends		Significant
	Z	p-value	
Ipoh	1.8457	0.0649	No
Kuala Krai	3.5294	0.0004	Yes
Mersing	7.8284	4.943E-15	Yes
Temerloh	5.9267	3.091E-09	Yes

Table 3 Mann-Kendall Trend Test of Rainfall Amount

Station	Mann-Kendal test trends		Significant
	Z	p-value	
Ipoh	2.7578	0.0058	Yes
Kuala Krai	2.0048	0.0450	Yes
Mersing	0.4418	0.6586	No
Temerloh	0.21871	0.8269	No

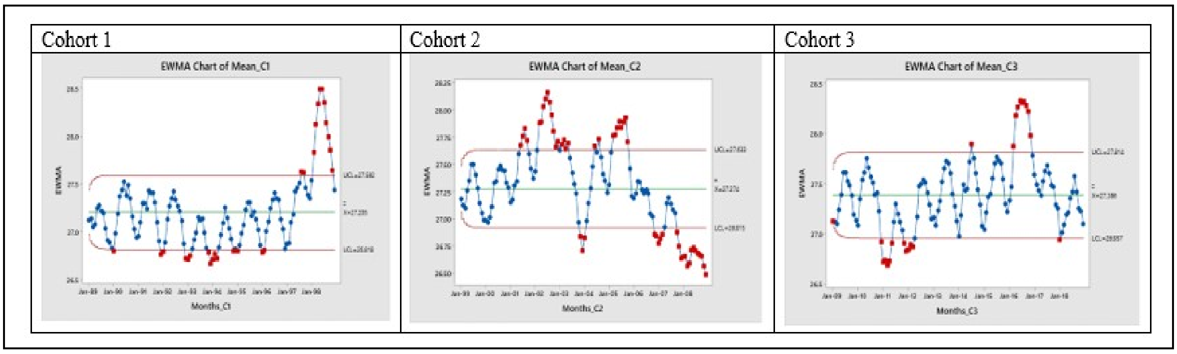
Based on Table 2, all stations except Ipoh show a significant increasing trend in mean temperature ($p < 0.05$). Meanwhile, the Mann-Kendall test results of rainfall amount in Table 3 show that Ipoh and Kuala Krai have a significantly increasing trend, while Temerloh and Mersing stations showed no significant trend. The increasing trend in Ipoh has a higher significance (p-value=0.0058) than Kuala Krai (0.0450). The reason for the changes is that the rainfall pattern in Ipoh is influenced by the Australian-Indonesian monsoon system, which brings increased rainfall and a higher risk of flooding. The monsoon system significantly impacts the rainfall, primarily by bringing a wet season during the northeast monsoon period (typically November to March) as the moist air from the north flows southward, delivering heavy rain to the east coast of Peninsular Malaysia and parts of Sabah and Sarawak (Gallagher et al., 2024). In addition, the city's proximity to mountainous regions may contribute to precipitation trends. This is because when moist air is forced to rise over the mountains, it cools and condenses, leading to high precipitation rates.

The long-term trend analysis in this study revealed the significant effect of climate change on the temperature in Kuala Krai, Mersing, and Temerloh. For rainfall amounts, stations Ipoh and Kuala Krai are shown to receive a significant effect but not for other stations. The effect pattern is shown as regional and spatially different. The results obtained for the rainfall trend in Table 2 are compared to previous research done by Suhaila and Yusop (2017). The investigation covered the Ipoh and Mersing stations from 1980 to 2011. Their results show that Ipoh has no significant trend with a Z value of 1.51 and a p-value of 0.07, while Mersing has a positive significant trend with a Z value of 2.62 and a p-value of 0.00.

3.2 Detection using Mean Shifting Assessment in EWMA Control Chart

The assessment based on the mean shifting of temperature and rainfall data from cohort to cohort is the emphasized approach to detect climate change existences by assessing its effect on meteorological variables in this study. The mean values of the temperature and rainfall data must represent the average values of the normal situation or normal environment process system within each cohort year. There is evidence of climate change effects if the normal mean shifts from the cohort before and after. Phase 1 control chart analysis results were used to find these shifting of normal means.

a)



b)

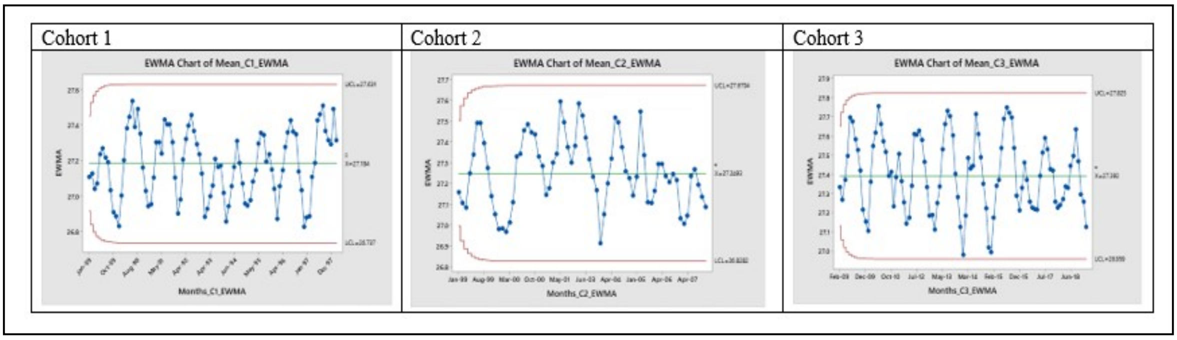


Figure 2. Phase 1 – Out of Control process data (a) In-Control (Normal) process data (b) of EWMA Chart for Temperature in Ipoh

Figure 2 (a) shows the sample of the physical form for Phase 1 EWMA Chart of mean temperature at two of the four selected study locations: Ipoh and Kuala Krai. Both stations showed that in all three cohorts, all EWMA charts have out-of-control points (anomalies), represented by red dots, and are out of the limits. These anomalies are observations that are beyond the norm levels. To obtain the in-control (normal) process data, these anomaly data need to be removed so that the remaining data can represent the normal process system (reflecting the average level) (see Figure 2 (b)).

Table 4 represents the UCL, CL, and CL values of EWMA charts from each Cohort for all study locations. It can be seen that the temperature level had increased from Cohort 1 to Cohort 3 for all locations. The mean temperature level had shifted to a higher level at all the study locations given by the increased CL values. For example, in Ipoh, the Temperature increased from 26.737 ºC during Cohort 1 to 26.8282 ºC during Cohort 2 and 26.959 ºC during Cohort 3. Similarly, the CL values also increased from 27.631 ºC during Cohort 1 to 27.6704 ºC (Cohort 2) and 27.825 ºC during Cohort 3. Similarly, mean shifting was shown in the Temperature average in Ipoh as the CL values increased from 27.184 ºC during Cohort 1 to 27.2493 ºC (Cohort 2) and 27.329 ºC (Cohort 3).

For rainfall amount, two locations experienced a positive mean shifting at the average of 195.9 mm (Cohort 1) to 236.3 mm (Cohort 2) and 234.9 mm (Cohort 3) in Ipoh and 166.7 mm (Cohort 1) to 178.5 mm (cohort 2) and 234.9 mm (Cohort 3) respectively. Meanwhile, Mersing and Temerloh show a reduction in the average rainfall amount, especially from Cohort 2 to Cohort 3. It seems that this direct effect of climate change is associated with the geographical locations of the stations. Ipoh and Kuala Krai are situated in the upper part of Peninsular Malaysia; meanwhile, Mersing and Temerloh are located in the middle.

Table 4. EWMA Chart Results of Mean Temperature (ºC)

	Cohort 1			**Cohort 2**			**Cohort 3**		
Stations	**UCL**	**CL**	**LCL**	**UCL**	**CL**	**LCL**	**UCL**	**CL**	**LCL**
Ipoh	27.631	27.184	26.737	27.6704	27.2493	26.8282	27.825	27.392	26.959
Kuala Krai	26.91	26.368	25.826	26.865	26.395	25.925	27.263	26.718	26.173
Mersing	26.7061	26.3481	25.9902	26.9459	26.5961	26.2462	27.3801	26.9942	26.6083
Temerloh	27.162	26.684	26.205	27.1142	26.7052	26.2961	27.764	27.295	26.827

Table 5. EWMA Chart Results of Rainfall Amount (mm)

	Cohort 1			**Cohort 2**			**Cohort 3**		
Stations	**UCL**	**CL**	**LCL**	**UCL**	**CL**	**LCL**	**UCL**	**CL**	**LCL**
Ipoh	276.8	195.9	115.0	338.8	236.3	133.9	335.5	234.9	134.3
Kuala Krai	271.9	166.7	61.6	260.3	178.5	96.8	303.4	192.5	81.7
Mersing	303.8	190.1	76.4	303.7	198.1	92.4	262.6	174.8	87.1
Temerloh	246.9	162.2	77.5	240.0	159.2	78.5	239.0	154.4	69.9

The results in Table 4 and Table 5 also indicate that the different locations have different average temperatures but are still within ±27 degrees Celcius. The pattern is the same for the rainfall amount, but there is quite a large difference in the average level between the stations and among the Cohorts. The results indicate a localized climate change effect on temperature and rainfall levels and patterns, varying by study location. The analysis proceeds to investigate whether there is a significant difference in the average temperature and rainfall amount among the three Cohorts.

Table 6 Kruskal-Wallis Test Results of Mean Temperature (ºC) for Each Station

Stations	P-value	Significant	Most affected Station (Raning)
Ipoh	0.119	No	4
Kuala Krai	0.008	Yes	3
Mersing	0.0001	Yes	2
Temerloh	0.0000	Yes	1

From the results in Table 6, based on the p-value of the Kruskall-Wallis test, at a 5% significance level, the difference in the average temperature shown in the previous analysis using the EWMA control chart is not significant among Cohorts in Ipoh but significantly different in Kuala Krai, Mersing, and Temerloh. Considering all the study locations, based on the ranking of the p-value (the smallest given the highest rank), the analysis revealed that the most affected location was Temerloh, followed by Mersing, Kuala Krai, and lastly, Ipoh.

A study by Suhaila and Yusop (2018) found that there is a significant increasing trend in the annual and seasonal mean, maximum, and minimum temperatures in Peninsular Malaysia from 1980 to 2011 and that the local mean temperatures also have increased in the range between 2°C and 5°C per 100 years. Other than that, another research, by Wong, Yusop and Ismail (2018), showed that at a 95% confidence level, there is:

Table 7 Kruskal-Wallis Test Results of Rainfall Amount (mm) for Each Station

Stations	P-value	Significant	Most affected Station (Ranking)
Ipoh	0.014	Yes	1
Kuala Krai	0.121	No	2
Mersing	0.772	No	3
Temerloh	0.895	No	4

In the context of the effect of climate change on rainfall variables, results in Table 7 show that the effect is not significant at all study locations except Ipoh. This provides evidence that Ipoh is the location affected the most by climate change on rainfall changes. The results in Tables 6 and 7 also suggest an opposite pattern of climate change effect between temperature and rainfall. Some stations experience significant effects of climate change on temperature levels but not on rainfall. A station that is the most affected by the long-term changes in temperature is the least affected by rainfall and vice versa.

4. Conclusion

Understanding climate change is crucial for urgent action to mitigate its impacts. It helps sustain life and a green environment by ensuring food, water, and biodiversity, supporting informed policies, and promoting innovation for sustainable solutions. This study addresses concerns about climate change and its effects on the Malaysian environment.

This study is exploratory, implementing the existing statistical analysis, including the Mann-Kendall Test to assess the pattern of long-term trends of two climate indicators, temperature and rainfall amount. This study has revealed that not all locations experienced a significant increasing trend in temperature and rainfall data. Among the four sample stations, data from Kuala Krai, Mersing, and Temerloh show a significant positive trend in the average temperature over 30 years (1989 -2018); meanwhile, for rainfall, only Ipoh and Kuala Krai experienced a significant positive trend. The rest of the stations were shown not to experience a significant increase or decrease trend.

The novelty of this study is the introduction of the application of a robust EWMA control chart to detect the effect of climate change on meteorological variables. Based on the mean shifting concept, this study can reveal a clear mean change between three Cohort years' data: Cohort 1 (1989-1998), Cohort 2 (1999-2008), and Cohort 3 (2009-2018). The cohort is defined as a group of data within the 10-year period that spans over 30 years (1918-2018). The application of the EWMA control chart clearly shows evidence of the climate change existence at the study locations whereby detected by the Kruskall-Wallis test, the most affected stations is Temerloh in the long-term temperature changes and Ipoh in the long-term rainfall changes. An opposite pattern of climate change effect between temperature and rainfall occurred. Some stations only experience significant effects of climate change on temperature but not on rainfall and vice versa. A station that has the most climate change effect in temperature is found to have the least effect on rainfall. Overall, based on the analysis results, this study concludes that there is a distinct localized effect of climate change on the meteorological variables of temperature and rainfall in this study. The study concludes that the effect is in situ; perhaps the contribution also comes from the surroundings factor. Policymakers must put policies in place that help communities adjust to the changing environment and lessen future effects to address the effects of climate change at the research locations. These include encouraging climate-resilient infrastructure, improving early warning systems and preparedness for disasters, encouraging sustainable land use and farming methods, bolstering public education and awareness about climate change, encouraging energy efficiency and renewable energy, and tightening policies related to carbon pricing and emission reduction.

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Author Contributions

Noor Kesuma prepared the literature review draft, acquired data, and conducted the analysis. Norshahida designed the research and the methodology framework and wrote the draft of the paper. Firdaus checked on the results and content. Nurain checked on writing flow and updated the literature, and Mahayaudin helped review the paper.

Conflict of Interest

The authors have no conflicts of interest to declare

References

Acuna, E., & Rodriguez, C. (2004). The treatment of missing values and its effect on classifier accuracy. In *Classification, clustering, and data mining applications* (pp. 639–648). Springer.

Ahmad, R. (2018), August 12). It's going to be hot until October. Retrieved from https://www.thestar.com.my/news/nation/2018/08/13/its-going-to-be-hot-until-october-intermonsoon-season-expected-to-bring-cooler-weather-says-dept/

Althor, G., Watson, J. E. M., & Fuller, R. A. (2016). Global mismatch between greenhouse gas emissions and the burden of climate change. *Scientific Reports*, *6*, 1–6.

Baba-Adamu, M., and Ibrahim, A.J. (2021). Environmental determinant of rural households' vulnerability to water scarcity in semi-arid Nigeria. *Malaysian Journal of Computing*, *6* (2), 778-797.

Febrina, W., & Fitriana, W. (2022). Exponential Weight Moving Average (EWMA) Control Chart for Quality Control of Crude Palm Oil Product. *International Journal of Management and Business Applied, 1*(1), 19-27.

Firdaus, R. B. R., Leong Tan, M., Rahmat, S. R., & Senevi Gunaratne, M. (2020). Paddy, rice and food security in Malaysia: A review of climate change impacts. *Cogent Social Sciences*, *6*(1), 1-17.

Gallagher, S. J., Korasidis, V. A., Auer, G., et al. (2024). Cenozoic history of the Australian monsoon. *Progress on Earth and Planetary Science, 11*(60), 1–32. https://doi.org/10.1186/s40645-024-00472-5

Gumus, V., Avsaroglu, Y., & Simsek, O. (2022). StreamCow trends in the Tigris river basin using Mann Kendall and innovative trend analysis methods. *Journal of Earth System Science 131*(34), 1-17.

Ibrahim, N.A., Alwi, S.R.W., Manan, Z.A., Mustaffa, A.A., & Kidam, K. (2024). Climate change impact on solar system in Malaysia: Techno-economic analysis. *Renewable and Sustainable Energy Reviews,* 189, Part A,113901.

Kamati, W., Hashiyana, V., & Mutuku, J. (2024). Development of a near real-time early warning agricultural system for disaster prediction. *Malaysian Journal of Computing*, 9(10), 1706-1721.

Kaur, M. (2019). Temperatures could hit 40°C in some parts of Malaysia, expert warns. Retrieved from https://www.freemalaysiatoday.com/category/nation/2019/02/27/temperatures-could-hit-40c-in-some-parts-of-malaysia-expert-warns/

Li, H., Deng, J., Yuan, S., Feng, P., & Arachchige, D.D.K. (2021). Monitoring and Identifying Wind Turbine Generator Bearing Faults Using Deep Belief Network and EWMA Control Chart. *Frontiers in Energy Research*, *9*, 1-10.

Li, C., Zwiers, F., Zhang, X., Chen, G., Lu, J., Li, G., Norris, J., Tan, Y., Sun, Y., & Liu, M. (2019). Larger increases in more extreme local precipitation events as climate warms. *Geophysical Research Letters*, *46*(12), 6885–6891.

Masson-Delmotte, V., Zhai, P., Pörtner, H. O., Roberts, D., Skea, J., Shukla, P. R., … Waterfield, T. (2018). *Summary for policymakers*. In *Global warming of 1.5°C: An IPCC special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of* *strengthening the global response to climate change*. Intergovernmental Panel on Climate Change (IPCC). Retrieved from https://report.ipcc.ch/sr15/pdf/sr15_spm_final.pdf

Mikhaylov, A., Moiseev, N., Aleshin, K., & Burkhardt, T. (2020). Global Climate Change and Greenhouse Effect. *Entrepreneurship and Sustainability Issues, 7(*4), 2897-2913

Noor, M.A.I.M., Halek, M.A., Faiz, A., Lim, L.M.R., & Ahmat, H. (2023). Rainfall Intensity Classification in The East Coast of Malaysia Using Discriminant Analysis*. Journal of Sustainability Science and Management*, *18*(7), 87-102.

Ostertagova, E., Ostertag, O., & Kovac, J. (2014). Methodology and Application of the Kruskal-Wallis Test. *Application Mechanics and Materials*, *611*, 115-120.

Pin, K. F., Pereira, J. J., & Aziz, S. (2013). Platforms of climate change: An evolutionary perspective and lessons for Malaysia. *Sains Malaysiana*, *42*(8), 1027–1040.

Redzuan, S.N., Mohamed Noor, N., Rahim, N.A.A., Jafri, I.A.M., Baidrulhisham, S.E., Ul-Saufie, A.Z., Sandu, A.V., Zainol, M.R.Z.M.A., & Deak, Gyorgy. (2023). Characteristics of PM10 Level during Haze Events in Malaysia Based on Quantile Regression Method. *Atmosphere*, *14*(407), 2-24.

Roberts, S. W. (1959). Control chart tests based on geometric moving averages. *Technometrics, 1*(3), 239-250.

Suhaila, J. (2015). Temporal changes and variability in temperature series over Peninsular Malaysia. *AIP Conference Proceedings, 1643*, 248–255. https://doi.org/10.1063/1.4907452

Suhaila, J., & Yusop, Z. (2018). Trend analysis and change point detection of annual and seasonal temperature series in Peninsular Malaysia. *Meteorology and Atmospheric Physics*, *130*(5), 565–581.

Tan, M. L., Samat, N., Chan, N. W., Lee, A. J., & Li, C. (2019). Analysis of precipitation and temperature extremes over the Muda River Basin, Malaysia. *Water (Switzerland)*, *11*(2), 1–16.

Wong, C. L., Yusop, Z., & Ismail, T. (2018). Trend of daily rainfall and temperature in Peninsular Malaysia based on gridded data set. *International Journal of GEOMATE*, *14*(44), 65–72.