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# Assessment of rainfall trend at the airports using non-parametric statistics approach

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## ABSTRACT

Rainfall plays an important role in generating hydrological cycles which in turn affects local micro-climate such as territories, municipalities and so on. This study attempts to identify trend and differences of annual precipitation across three airports in Peninsular Malaysia namely Kuala Lumpur International Airport, Sultan Abdul Aziz Shah Airport and Senai International Airport. Mann-Kendall and Sen's slope estimator were used to identify monotonic trend for rainfall distribution meanwhile, Kruskal-Wallis is used to determine if samples come from the same distribution. Analysis shows existence of positive monotonic trend for Abdul Aziz Shah Airport and Senai International Airport while there is no significant trend at Kuala Lumpur International Airport. Kruskal-Wallis test shows that annual precipitation from the three airports are different and do not come from the same population. Investigating the trend of climate change parameters is very important for future analysis since climate change impacts most global issues.

**Key words:** Rainfall distribution trend; Mann-Kendall trend test; Sen's Slope test; Kruskal-Wallis test.

## 1. INTRODUCTION

Precipitation is known as one of the most complex phenomena and precise estimation in a long run remains a challenge. It is important to have a precise estimation of rainfall in a long run since it is used by various sector such as water resource management, food production and flood mitigation [1]. There are several huge factors such as El Nino southern Oscillation (ENSO) and Indian Ocean Dipole (IOD) which affect rainfall pattern specifically at India, Australia and America. There are few studies worldwide on determination of relationship between the climate model and various rainfall data types [2], [3].

It is one of vital parameter in determining surface water sources. It is regarded as an input in generating hydrological cycles which in turn affects local micro-climate such as territories, municipalities and so on. Change in climate contribute to major impact on hydrologic cycle. In other words, the effects can be seen through availability of water resources, ecosystem including natural and man-made, society and economy [4]. Report from National Hydraulic Research Institute of Malaysia (NAHRIM) showed there has been an increasing amount of rainfall since 2000 by 17% compared to 1970 [5]. Knowledge in meteorology field is important since it affects both, human life and country development. Climate change leads to huge changes in climates factors such as rainfall [6], temperature, relative humidity and solar radiation [7]. Estimation with regards of duration and amount of rainfall is rather a difficult process. Unstable pattern of rainfall cause problems for extreme rainfall prediction which potentially leads to environmental disasters such as flash floods. In Malaysia, floods and flash floods occur in tradition, specifically in east coast areas during monsoon season [8].

Weather is an important aspect that affects air traffic management. In other words, various automated meteorological forecast products are needed as air traffic management tools. Air traffic management research has been using several methods and detailed practices for modelling the terminal area and airport capacity. Many methods used in order to validate the accuracy of precipitation forecasts [9].

Weather prediction specifically at airports consist of precise meteorological conditions on a period of time [10]. The estimation of meteorological parameters at airport is called Terminal Aerodrome Forecast (TAF), which construct by a group of experts with depth knowledge on behavior of large and local scale weather phenomenon at specific airports. The prediction is conducted using basic PC along with computer-model-assisted statistical forecasting approach on local area. As weather prediction is a complex and difficult task for Malaysian Meteorological Department (MMD). Among all parameters stored, rainfall is the most unpredictable. Water resources management in Malaysia is always looking for more practical methods and techniques for predicting rainfall distribution. MMD faces problems in analyzing the increasing number of meteorological data. Furthermore, due to practical value of weather forecasts in the meteorite, it leads to time series forecasting problem in scientific research [11].

The techniques of trend detection had attract the attention and interest of researchers over the decades [12], particularly in the studies of climate change namely temperature and rainfall [13][14]. Several studies over India observed no significant trend in mean of rainfall [15]. Despite non-presence of monsoonal rainfall trend in India, there is a significant trend present on a regional scale [16], [17]. In conclusion, intense precipitation rate is reduced in most Asian country, and the same goes to number of rainy days and annual rainfall [18], [19].

Capacity of airports is influenced by several meteorological phenomenon such as a very high wind speeds will make airport operations more difficult. Extreme wind speeds can also stop and interfere with operations on the airfield. The thunderstorm can reduce the airspace capacity and disrupt the arrival or departure flow. Defective airport surface conditions, such as wet pavements, can slow the brakes and thus reduce the runway capacity. Study on rainfall trend in a long-term is important and relevant in hydrological studies, particularly as a tool for detecting and identifying changes in hydrological systems, water management planning and management in drainage basins. Basically, this study is important since the intensity of rainfall can be expected. The need to make future expectations is very important. For example, initial action can be taken if rain intensity from the model to be of high value. Hence, this study is very vital in assisting the air transportation system. Safety and efficiency in air transport should be emphasized. Therefore, the impact towards weather under present and future climate conditions is important to enable related organization to make adequate adjustment and preparation.

There are two objectives for this study. Firstly, is to identify rainfall trend and the latter is to determine annual rainfall difference between three airports namely Kuala Lumpur International Airport, Sultan Abdul Aziz Shah Airport and Senai International Airport.

## 2. DATA AND METHODOLOGY

This study considers monthly precipitation data between 1970 to 2011 at Kuala Lumpur International Airport (2.7456$^0$ N, 101.7072$^0$ E), Sultan Abdul Aziz Shah Airport (3.1328$^0$ N, 101.5544$^0$ E) and Senai International Airport (1.6382$^0$ N, 103.6691$^0$ E). The location of the airports is shown in Figure 1. Mann Kendall trend test is used to identify pattern and trend of rainfall data followed with Kruskal-Wallis test to determine annual precipitation difference between these three airports.

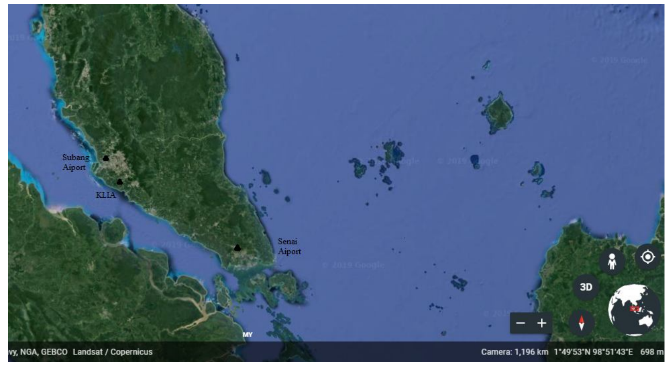


**Figure 1:** Airport locations in Peninsular Malaysia

### 2.1 Mann-Kendall Trend test

Trend evaluates direction whether moving upward or downward [20]. Mann-Kendall trend test is a non-parametric statistical test which is used in broad area including climate parameter [21] and time series [22]. Trend analysis is a tool used to explain variation of a variable over time. Non-parametric Mann-Kendall is widely used especially in hydro-meteorological data [23]. Compared to parametric statistical tests, this test is considered more appropriate for hydro-meteorological data which not normally distributed [23]. Hypothesis testing for Mann-Kendall are:

$H_0$: There is no trend in the data set
$H_A$: There is trend in the data set

Acceptance of null hypothesis, $p>0.05$ implies that the data is independent and random [24]. On the other hand, when $p<0.05$, there is a statistically significant trend in the series [25].

Based on Mann (1945) and Kendall (1975), statistical test for Mann-Kendall is calculated as:

$$S = \sum_{k=1}^{n-1} \sum_{j=k+1}^{n} sgn(x_j - x_k) \quad (1)$$

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

where $n$= number of data points; $x_j$ and $x_i$ = Data value in time series; sgn($x_j - x_k$) the sign function.

The variance is calculated as:

$$VAR(S) = \frac{1}{18}[n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5)] \quad (3)$$

Standard statistical test $z$ is calculated as:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(S)}} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \frac{S+1}{\sqrt{Var(S)}} & \text{if} \quad S < 0 \end{cases} \tag{4}$$

A positive value (negative) *z* showed an increase (decrease) trend [26]. $H_0$ is rejected if the value $|Zs|$ is greater than the value $z\alpha/2$, hence, the null hypothesis is not valid with the understanding that there is a significant trend [27].

2.2 Sens's Slope Estimator

Mann-Kendall study on present of trend, while Sen's slope estimator supports the study by calculating the slope of the present trend (changes per unit time in the hydro -meteorological series). The method is robust to outliers [29] and is appropriate to determine presence of trends [32]. The trend slope gives the rate of increase or decrease in linear trend and direction of change [16], [32] and it involves the calculation of the slope for all ordinal point-time pairs and then using this median slope as an overall slope estimate [30]. The linear model for this method can be describe as [35]:

$$f(s) = Qt + D \tag{5}$$

where, *Q*, *D* and *t* represents slope, constant, time respectively. All possible pairs of different, $(x_i, x_j)$ for $j > i$ are considered. For each pair, the approximate slope of a simple pairing was calculated as follow [35]–[37]:

$$m_{ij} = \frac{(x_j - x_i)}{(j-i)} \tag{6}$$

With sample size *n*, there should be a sum of $N = n(n-1)/2$ as the pairing slope estimate ($m_{ij}$). The median of slope is calculated as below, where the arrangement of N the approximate slope of the slope ($m_{ij}$) in ascending order.

$$Q = \begin{cases} m_{\left(\frac{N+1}{2}\right)} & \text{if } N \text{ is odd} \\ \left(\frac{m_{\left(\frac{N}{2}\right)} + m_{\left(\frac{N+2}{2}\right)}}{2}\right) & \text{if } N \text{ is even} \end{cases} \tag{7}$$

Q indicates a reflection of the data trend, while the value shows a trend steepness [38]. If Q gives a positive value, then it shows an increasing trend, while negative values show a decreasing trend [31], [39].

2.3 Kruskal-Wallis test

In order to apply this test, random sample is taken to ensure independent for each group. The data should be in ordinal form. Hypotheses testing are:

$H_0$: Samples are from identical populations.
$H_A$: Sample comes from different populations.

Kruskal-Wallis can be conducted as follow:
1. Data is arranged and rank in ascending order. If tied value present, the average rank is taken into calculation.
2. Test statistics calculated as:

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} \frac{r_i^2}{n_i} - 3(n+1) \tag{8}$$

H= Test statistic
n= Total number of observations in all groups
$n_i$= Number of observations in group *i*
$r_i$= Rank of the group *i*

If $H_{calc} < H_{Table}$, null hypothesis is accepted and otherwise.

## 3. RESULTS

### 3.1. Descriptive Analysis

Statistical analysis and boxplots of total rainfall distribution at Kuala Lumpur International Airport (KLIA), Sultan Abdul Aziz Shah Airport (Subang) and Senai International Airport is shown in Table 1 and Figure 2.

**Table 1:** Statistical analysis of total rainfall

| Location (airports) | Rainfall Min. (mm) | Rainfall Max (mm) | Mean (mm) | Standard Deviation |
|---|---|---|---|---|
| Subang | 188.702 | 17375.800 | 4845.141 | 3196.952 |
| KLIA | 698.500 | 11130.280 | 4285.074 | 2082.320 |
| Senai | 200.660 | 23042.880 | 5205.374 | 2699.753 |

Based on Table 1, the minimum and maximum of total rainfall among the three airports is at Subang Airport with 188.702 mm and 17375.800 mm respectively. The highest mean of monthly rainfall is at Senai International Airport with 5205.374 mm while the lowest mean is at KLIA with 4285.074 mm. Standard deviation at Subang, KLIA and Senai airport are 3196.952, 2082.320 and 2699.753 mm respectively.

### 3.2. Mann-Kendall trend test

Mann Kendall test statistics are calculated in Table 3.

**Table 2:** Mann-Kendall Trend Test Results

| Location | Kendall's tau | p-value |
|---|---|---|
| Subang | 0.327 | 0.0001 |
| KLIA | -0.009 | 0.894 |
| Senai | 0.067 | 0.040 |

Based on Table 2, precipitation shows a monotonic trend in Sultan Abdul Aziz Shah Airport with *p<0.05*. Rejection of $H_0$ while it is true is lower than 0.01%. However, there is no significant trend in KLIA because *p>0.05*. Rejection of $H_0$ while it is true is 89.44 %. Lastly, there is a monotonic trend that can be seen at Senai International Airport with p<0.05. The risk to reject the null hypothesis $H_0$ while it is true is lower than 3.99%.

### 3.3 Sen's Slope Estimator

Sen's Slope determine the magnitude or slope of trend determined by Mann-Kendall test. The calculated magnitude is as follow:

**Table 3:** Sen's slope estimator

| Location | Sen's Value | Interval |
|---|---|---|
| Subang | 10.84 | [9.312,12.261] |
| KLIA | -0.717 | [-6.163,3.692] |
| Senai | 2.063 | [0.524,3.635] |

Sen's values in Table 3 shows Subang and Senai International Airport with increasing trend of 10.84, and 2.063 respectively, which shows an upward of the trend. Meanwhile, the Sen's value for KLIA is -0.717, indicating a decreasing trend.

### 3.4. Kruskal-Wallis test

**Table 4:** Kruskal-Wallis test results

| | |
|---|---|
| **K (Observed value)** | 13.686 |
| **P-value** | 0.001 |

From Table 4, the *p*-value is 0.001. Since *p*<0.05, $H_0$ should be rejected and $H_\alpha$ is accepted. The rejection of H0 while it is true is lower than 0.11%. So, it can be concluded that all three samples are different and do not come from the same population.

## 4. DISCUSSION

Trend analysis requires long time series data. According to [40], one of the things that are important is analyzing time series data for long term to detect trend of a variables such as rainfall data, temperature, total discharges, etc. For example, a prediction of long-term rainfall trends will help us to predict the rainfall either increasing or decreasing and be able to identify phenomena that possibly will occur such as floods, droughts and changes in the variations of discharge in the drainage basin.

In this research, there is a monotonic trend at Subang and Senai International Airport. So, when the result shows any significant monotonic trend for the climate change parameters, it can give a big insight to the researcher to determine and make an early judgement about the climate change in Malaysia. However, if the parameters do not show any monotonic trend such as in Kuala Lumpur International Airport, future investigation is needed to know the overall general trend for the parameters through the years. Early detection is crucial as it gives little information about the parameters and how far it can affect the climate change in the future.

[12] discovers an increasing trend of rainfall and wet days frequency during northeast monsoon between 1971-2004. The trend affects rainfall intensity at the location. This is supported by [41], for different period of 1975–2004. According to the result, several factors could contribute to this issue such as increase in human activity which alter climate system. On the other hand, this could also affect global warming. High amount of rainfall during short period of time had contributed to most flooding issue in Malaysia. In order to overcome damages from flooding, Malaysia government had spent millions of ringgits for the past year. Increase in the number of flash flood, landslide is reported due to increase in the rainfall intensity in Malaysia.

## 5.CONCLUSION

This research applied statistical analysis on total rainfall distribution at Kuala Lumpur International Airport (KLIA), Sultan Abdul Aziz Shah Airport (Subang) and Senai International Airport. From this research, it gives some understanding about pattern in environmental change parameters in the areas. Mann-Kendall trend test is an appropriate method to be utilized for environmental and climate contemplates. Overall, the consequences of the Mann-Kendall trend test and Kruskal-Wallis test gave a decent outcome in the identification of the trend for rainfall distribution. There is positive monotonic trend at Subang and Senai aiports as reported by the test statistics value using both Mann-Kendall and Sen'slope estimator. The two techniques can be utilized as a part of foreseeing and estimating a trend especially for rainfall distribution in KLIA, Subang and Senai International Airport. The rainfall distribution for these three airport stations is completely different between each other as tested using Kruskal-Wallis test. This study can be extended for further analysis, such as in identifying significant correlations among the climate change parameter such as radiation and wind speed.

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