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Research paper

Temporal Pattern of Sea Levels in Malaysia

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Abstract

Sea level rise would be expected to have several impacts, particularly on Malaysia coastal systems such as changes in sedimentation, erosion, flooding and groundwater inundation, storm surge and waves, and sea water intrusion. The purpose of this study is to analyzes the trend variation of sea level rise (SLR) and modelling the SLR for selected locations in Peninsular Malaysia. To examines the trend of the SLR, the curve estimation method, non – parametric Mann – Kendall test and Theil-Sen Trend Line test were used. Then, SLR is modelled in each tidal station. From the analysis, the results showed that all the selected stations in Peninsular Malaysia; Port Klang for hig h tide – no significant trend and for low tide – downward trend, Bagan Datuk for high tide – upward trend and for low tide – no significant trend and Permatang Sedepa for high tide – upward trend and for low tide – no significant trend. This study is important especially for civil engineers, to provide possible solutions to mitigate or eliminate the effects from sea level fluctuations.

Keywords: *curve estimation method; high and low tide; Kruskal-Wallis test; Mann-Kendall test; sea level; Theil-Sen Trend Line test*

1. Introduction

Sea level rise has been a huge threat to low-lying coastal areas around the world since the issue of human-caused - global warming observed in the 1980s [1]. It says that sea levels are rising and are expected to continue to rise for centuries, even if greenhouse gas emissions are cut off and the concentration of stable atmosphere [2]. Rising sea levels pose a threat to countries with high population and socio-economic activities in coastal areas [3]. This situation concerns many parties.

The tide is the periodic movement of sea waters caused by changes in attractiveness between the Moon and the Sun as the Earth rotates [4] [5] [6] [7]. In most places, tidal changes occur twice daily. Tides rise to maximum heights, called high tide, and then fall to a minimum level called low tide [8]. Rates of rise and fall are not uniform. From low water, the current starts up slowly at first, but at an increased rate of up to about half to high water. The rate of increase then decreases so high water is reached, and the increase is stalled. The tide drops the same way. The period when the water is high or low where there is no clear level change is called the stand. The height difference between high and low water is the range [9].

In the last 26 years ago, sea level was measured by multi-mission satellite, launched and operated by various agencies airspace around the world and they have jointly identify not only an increase of about 3 mm / year in the average global sea level, but also regional differences from the global average rating [10]. According to [11], the average global sea level rises at least 10 centimeters in the 20th century, and this increase is expected to continue and is likely to accelerate because of warming by humans in the 21st century. In the 21st century, sea level rise rates are expected to be several times higher than measured over the last century [12]. Recent projections suggest that sea levels may be ~ 0.6-1.5 m higher than now in 2100, and ~ 2m higher just under extreme scenarios. The expected global average rise of this sea level will have serious implications for the coastal community [13].

In general, variations in sea levels are attributed to two major factors, astronomical and non-astronomical factors [14] [15]. The astronomical factor is the influence of the attraction between the celestial bodies, especially the moon and the sun [4] [6] [16], which is a natural form of nature. Meanwhile, for non-astronomical factors, it is caused by global climate change [14] [17]. One of the impacts of climate warming is the rise in sea levels, which is the result of two major processes, namely sea thermal expansion, and increased glacial melt and other ice mass [18].

Sea levels constantly fluctuate with changes in global temperature [19], where changes in temperature can be attributed to global climate change. Current climate warming may be suitable for natural warming but it is exacerbated by anthropogenic activity [20] such as industrialization, urbanization, fossil fuel consumption and excessive farming and livestock that release high greenhouse gases into the atmosphere [21]. Globally, sea level rise in the 20th century has been in the range of 1 to 2 mm / year and due to global warming, this rate is expected to increase to between 1 and 7 mm / year, with a central budget of 4 mm / year [22]. Increased climate warming, affecting sea level rise, where this increase led to two main processes, namely the thermal expansion of seawater and increased glacial melt and other ice masses [18]. Thus, in terms of climate warming, the average global sea level is expected to increase, and will have serious implications for coastal communities [13] especially the communities who are living in low-lying coastal areas [23].

The ocean acts as a store for carbon through the carbon dioxide cycle which forms part of the larger carbon cycle [24]. Most of the additional heat is stored in the oceans, causing heat expansion by sea water and global sea level rise. Previous studies have shown that even after the cessation of emissions CO_2 or concentration of CO_2 stable, the global average surface air temperature will be stable or declining slowly, but sea levels will continue to rise [25]. New estimates suggest that increased glacier melt, and ice mass contribute about 1.2 mm a year will increase global sea levels. Relatively dynamic response melting icebergs in Greenland and Antarctica rapid response due to warming temperatures and increased rainfall has contributed to a rise in sea level of up to 0.7 mm per year [26]. However, the upcoming probabilities associated with several catastrophic events like monsoon, El Nino-Southern Oscillation (ENSO) and Indian Ocean Dipole cannot be appropriately determined [27].
In view of that, this study will focus on the 1) investigates the sea level trend in the study area from 2004 until 2017, using Mann – Kendall Test and Theil – Sen Trend Line Test 2) endeavors to project future sea level rise in selected tidal station for the years of 2050 and 2100, using curve estimation model and 3) compare the sea level between the stations.

2. Materials and Methods

2.1 Study area and monitoring sites:

For this study, daily mean sea level data from the years of 2004 till 2017 were used. All these data were obtained from NAHRIM and Pusat Cerapan Bumi, UKM. The study focused on 3 tidal stations (Port Klang, Bagan Datuk and Permatang Sedepa) of Peninsular Malaysia. A total of 15330 (14 years x 365 days x 3 stations) data points were generated from the tide data.

Fig. 1: Map of tidal stations

Trend analysis can be defined as the use of empirical approaches to measure and explain the changes in system over time [28]. In general, trends occur in two ways: changes gradually over time in a consistent direction (monotonic) or a sudden change in a certain place at a time (step trend) [29]. So, in this study a few methods were used to produce a fitted line graph based on the previous tide gauge data. From this graph an equation will be produced, and it will be used to model sea level rise.

2.2. Non-Parametric (Mann – Kendall Test)

When the assumption of linear regression cannot be verified at least approaching, the trend of non-parametric methods should be considered as a substitute [30]. Kendall test for Theil – Sen trends and trend lines can be extremely valuable when constructing trends on data sets containing non-detectors [31]. Mann-Kendall nonparametric usually used to detect monotonic trends in data series of the environment, [32], hydro-climate [33] [34] and meteorology [35]. One of the advantages of this method is the required data does not comply with any distribution [36] [37].
Statistical trend analysis is a hypothesis testing process. Null hypothesis $(\boldsymbol{H_0})$, that there is no trend in the time series of alternative hypotheses, $(\boldsymbol{H_a})$, that there is a trend in a time series for the special interests; each test has its own parameters to accept or reject $\boldsymbol{H_0}$. Failure to reject $\boldsymbol{H_0}$ does not prove that there is no trend but indicates that the evidence is insufficient to conclude with the level of confidence set that the trend exists [38] [29] [39] [40].

The Mann-Kendall statistic is computed as followed [41] [37] [42] [31]:

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

The data set was ordered by sampling event or time of collection, $\boldsymbol{x_1, x_2}$ to $\boldsymbol{x_n}$. Then all possible differences between distinct pairs of measurements, $\boldsymbol{(x_j - x_k)}$ for $j > k$ was considered. For each pair, compute the sign of the difference, defined by:

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

The normal test statistic Z was calculated as follows:

$$Z = \begin{Bmatrix} \frac{S-1}{\sqrt{\text{Var}(S)}} & \text{if} \quad S > 0 \\ 0 & \text{if} \quad S = 0 \\ \frac{S+1}{\sqrt{\text{Var}(S)}} & \text{if} \quad S < 0 \end{Bmatrix} \tag{3}$$

where variance S can be defined as followed:

$$V(S) = \frac{1}{18}[\, n(n-1)(2n+5) - \sum_{p=1}^{g} t_p(t_p-1)(2t_p+5) \tag{4}$$

where n is the number of data points, g is the number of bound groups (bound group is a set of sample data that has the same value, and t_p is the number of data points in the p_{th}group)

Results for the trend in the study was assessed at the 5% significance level. This indicates that the null hypothesis is rejected when $|Z| \geq Z_{\frac{\alpha}{2}}$ in the above equation at the significance level, $\alpha = 0.05$. Alternative hypothesis is a trend that exists in data. The positive Z value indicates an upward trend, while for the Z value is negative, it shows a downward trend [43] [44] [45]. The significant level (p-value) for each trend test can be obtained from the given relationship:

$$p = 0.5 - \varphi(|Z|) \tag{5}$$

where $\varphi(|Z|)$ refers to the cumulative distribution function (CDF) of the normal standard variables. At a significance level of 5%, if $p \leq 0.05$, the existing trend is statistically significant [46] [42].

Kendall's rank correlation measures the strength of monotonic equation between vectors *x* and *y*. The statistical τ is defined as the difference between the probability of concordance and the contradiction between the two variables [47] [48]. In case there are no ties in the variables *x* and *y*, Kendall's rank correlation coefficient, ever, can be expressed as [49] [32]:

$$\tau = \frac{S}{D}$$

$$D = \left[\frac{1}{2}n(n-1) - \frac{1}{2}\sum_{p=1}^{g} t_p(t_p-1)\right]^{\frac{1}{2}} \left[\frac{1}{2}n(n-1)\right]^{\frac{1}{2}} \tag{6}$$

where *S* is referred to as score and *D*, the denominator is the maximum possible value for *S*.

2.3. Theil-Sen Trend Line

The Mann-Kendall Procedure is a non-parametric test for significant slope in linear regression for data values over sampling time. But Mann-Kendall S does not indicate the magnitude of the gradient or estimate the trend line itself although there is a trend. Theil-Sen trend line is a non-parametric alternative to linear regression that can be used in conjunction with the Mann-Kendall test [31]. Sen estimators are used to determine the magnitude of the trend [50], (changes per unit time in the hydro-meteorological series). The advantages of this method; it is insensitive to outliers [51] [52] and can be used effectively to measure trends in data [53] [54]. The trend slope gives the rate of increase or decrease in trend and direction of change [55]. This method can be applied if the linear trend is present in the time series [56] 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 [54].

The linear model for this method can be describe as [57] [58]:

$$f(s) = Qt + D \tag{7}$$

Where, Q is the slope, D is a constant and t is time. 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 [59] [45] [31]:

$$m_{ij} = \frac{(x_j - x_i)}{(j-i)} \tag{8}$$

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 or Sen's slope estimator is computed as below, where the arrangement of N the approximate slope of the slope (m_{ij}) from at least to the largest.

$$Q = \begin{cases} m_{\left(\frac{[N+1]}{2}\right)} & if\ N\ is\ odd \\ \left(\frac{m_{\left(\frac{N}{2}\right)} + m_{\left(\frac{[N+2]}{2}\right)}}{2}\right) & if\ N\ is\ even \end{cases} \tag{9}$$

The Q indicates a reflection of the data trend, while the value shows a trend steepness [60]. If Q gives a positive value then it shows an upward trend, while negative values show a downward trend [53] [61]. When significant trends in data are detected, 95% confidence interval is calculated using non-parametric techniques. Quantity $C_\alpha$was first calculated as:

$$C_\alpha = Z_{1-\alpha/2}\sqrt{VAR(S)} \tag{10}$$

where Z is the standard deviation, VAR (S) is as previously stated, and α is taken as 0.05. Index $M_1$and M_2 are determined from:

$$M_1 = \frac{N - C_\alpha}{2} \tag{11}$$

$$M_2 = \frac{N + C_\alpha}{2} \tag{12}$$

where N is as defined previously. Finally, confidence limits are defined by the largest M_1th and $(M_2 + 1)$th of the ordered estimates *Q*, with corresponding interpolation for non-integer values M_1 and M_2 [62] [63].

2.4 Linear Regression Model

Linear regression is used to examine the linear relationship between dependent variable *Y* and one or more independent variables *x* [63]. The initial assumption of the possible relationship between the two continuous variables must always be made based on scattered plot (scattered graphs) and this type of plot will indicate whether the relationship is linear or non-linear. Performing linear regression makes sense only if the relationship is linear [64]. By way of interpretation, each point along a linear regression trend line is an estimate of the true mean concentration at that point in time. Thus, a linear regression can be used to assess if the population mean at a compliance well has significantly increased or decreased [31]. Linear regression can also be used to predict / model [65] the value of one variable, when the values of the other variables are given [66].

$$\boldsymbol{Y} = \boldsymbol{\beta_0} + \boldsymbol{\beta_1 x} + \in \tag{13}$$

The above equation is a linear regression model that can be used to explain the relationship between *x* and *Y* based on plot scattering. x and Y in this equation represent time and sea level respectively Slope, $\boldsymbol{\beta_1}$and intercept, $\boldsymbol{\beta_0}$for line is called regression coefficient. Slope, $\boldsymbol{\beta_1}$ can be interpreted as a change in the mean value, *Y* for unit changes in *x*. The term random error, ∈ is assumed to follow the normal distribution with an average of 0 and variance, $\boldsymbol{\sigma^2}$. The slope shows the direction of changing trend: the trend is increased if the slope is positive and decreases if the slope is negative [67]. Estimated regression lines, obtained using the values $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_0}$, are called the fitted line. Estimated least squares $\boldsymbol{\beta_1}$ and $\boldsymbol{\beta_0}$, can be obtained using the following equation:

$$\beta_1 = \frac{\sum_{i=1}^{n} y_i x_i - \frac{(\sum_{i=1}^{n} y_i)(\sum_{i=1}^{n} x_i)}{n}}{\sum_{i=1}^{n}(x_i - \bar{x})^2} \tag{14}$$

$$\boldsymbol{\hat{\beta}_0} = \boldsymbol{\bar{y}} - \boldsymbol{\hat{\beta}_1 \bar{x}} \tag{15}$$

where $\boldsymbol{\bar{y}}$ is the mean of all observed values and $\boldsymbol{\bar{x}}$ is the mean of all predicted variable values in which observation is taken.$\boldsymbol{\bar{y}}$ and $\boldsymbol{\bar{x}}$ are calculated using $\boldsymbol{\bar{y}} = \frac{\sum_{i=1}^{n} y_i}{n}$ and $\boldsymbol{\bar{x}} = \frac{\sum_{i=1}^{n} x_i}{n}$.

A fitted regression line can be written as:

$$\boldsymbol{\hat{y}} = \boldsymbol{\hat{\beta}_0} + \boldsymbol{\hat{\beta}_1 x} \tag{16}$$

where $\boldsymbol{\hat{y}}$ the appropriate value or estimated by the regression model. The difference between the observed value, $\boldsymbol{y_i}$ and the value given by the predicted variable, $\boldsymbol{\hat{y}_i}$is called residual, $\boldsymbol{e_i}$ [68]:

$$\boldsymbol{e_i} = \boldsymbol{y_i} - \boldsymbol{\hat{y}_i} \tag{17}$$

T test was used to test hypothesis on regression coefficients obtained in a simple linear regression. Statistics based on t distribution are used to test the two-sided hypothesis which is the real slope, $\boldsymbol{\beta_1}$equals some constant value, $\boldsymbol{\beta_{1,0}}$. The statement for hypothesis testing is stated as:

$$\boldsymbol{H_0}: \boldsymbol{\beta_1} = \boldsymbol{\beta_{1,0}} \tag{18}$$

$$\boldsymbol{H_1}: \boldsymbol{\beta_1} \neq \boldsymbol{\beta_{1,0}} \tag{19}$$

The statistical tests used for this test are:

$$\boldsymbol{T_0} = \frac{\boldsymbol{\hat{\beta}_1} - \boldsymbol{\beta_{1,0}}}{\boldsymbol{se(\hat{\beta}_1)}} \tag{20}$$

where $\boldsymbol{\hat{\beta}_1}$is the least square of estimates $\boldsymbol{\beta_1}$, and $\boldsymbol{se(\hat{\beta}_1)}$ is the standard error. The value of $\boldsymbol{se(\hat{\beta}_1)}$ can be calculated as follows:

$$(\boldsymbol{\hat{\beta}_1}) = \sqrt{\frac{\frac{\sum_{i=1}^{n} e_i^2}{n-2}}{\sum_{i=1}^{n}(x_i - \bar{x})^2}} \tag{21}$$

Statistical test $\boldsymbol{T_0}$, according to the t distribution with $(\boldsymbol{n-2})$degree of freedom, where n is the total number of observations. The null hypothesis, $\boldsymbol{H_0}$is accepted if the statistical value of the test is as follows:

$$-t_{\frac{\alpha}{2},n-2} < T_0 < t_{\frac{\alpha}{2},n-2} \tag{22}$$

where $t_{\frac{\alpha}{2},n-2}$ and $-t_{\frac{\alpha}{2},n-2}$ critical value for two-sided hypothesis. $t_{\frac{\alpha}{2},n-2}$ is the percentile of the t distribution corresponding to the cumulative probability of $\left(1-\frac{\alpha}{2}\right)$ and α represents significance level. If the $\beta_{1,0}$ used is zero, then the test shows if the appropriate regression model is the value in explaining the variation in observation or if trying to impose a regression model when no true relationship exists between *x* and *Y*. Failure to reject H_0: $\beta_1 = 0$ indicates that no linear relationship exists between *x* and *y*.
The Coefficient of Determination (R^2) is a measure of the amount of variability in the data taken by the regression model. The determination coefficient is the ratio of the total squared regression to the total sum of squares.

$$\boldsymbol{R^2} = \frac{\sum_{i=1}^{n}(\hat{y}_i-\bar{y})^2}{\sum_{i=1}^{n}(y_i-\bar{y})^2} \quad (23)$$

where $\boldsymbol{R^2}$ can take values between 0 and 1.

2.5 Curve Estimation Model

Apart from the linear regression model, several other models known as curve estimation model were also used in the analysis of this study. Among the models are as shown below [69] [70] [71], where *x* represents the time and *Y* is sea level. Tests using these models are important to investigate the performance of different statistical procedures for the appropriate power curve and determine which method best results for the given data set.

Table 1: Curve estimation model with their expression

Model	Expression	
Linear	$Y = \beta_0 + \beta_1 x$	(23)
Logarithmic	$Y = \beta_0 + \beta_1 \ln(x)$	(24)
Inverse	$Y = \beta_0 + \frac{\beta_1}{x}$	(25)
Quadratic	$Y = \beta_0 + \beta_1 x + \beta_2 x^2$	(26)
Cubic	$Y = \beta_0 + \beta_1 x + \beta_2 x^2 + \beta_3 x^3$	(27)
Compound	$\ln Y = \ln \beta_0 + (\ln \beta_1) x$	(28)
Power	$\ln Y = \ln \beta_0 + \beta_1 \ln(x)$	(29)
Sigmoid (S)	$\ln Y = \beta_0 + \frac{\beta_1}{x}$	(30)
Growth	$\ln Y = \beta_0 + \beta_1 x$	(31)
Exponential	$\ln Y = \ln \beta_0 + \beta_1 x$	(32)

2.6 Kruskal – Wallis Test

One-way ANOVA parametric make major assumptions that remains normally distributed data. If these assumptions are not suitable or cannot be tested because most are undetectable, non-parametric ANOVA can be carried out using observation ranks rather than original observations. Kruskal – Wallis tests are offered as non-parametric alternatives to one-way F-test when some groups need to be simultaneously compared, for example when evaluating spatial diversity patterns. In addition to the average test, Kruskal – Wallis examined the difference among parity-equivalent parameters. The Kruskal – Wallis statistical test, *H*, has no intuitive form of Student t-test. Under the null hypothesis that all sample measurements are of the same parent population, Kruskal – Wallis statistics follow the famous chi-square statistics distribution. Critical points for the Kruskal – Wallis test can be found as a percentage point above the chi square distribution $(\chi^2_{1-\alpha,df})$. If *H* shows a significant difference between the population, individual post - hoc comparisons between each adherence well and the background need to be exercised if Kruskal – Wallis is used for formal compliance testing. Post - hoc contrast is usually not necessary to identify spatial diversity. On the other hand, from Bonferroni's t-statistics, contrast is based on data positions and approximations following the standard normal distribution [59] [45] [31]. The computational formula for the test statistic, H, is:

$$\mathbf{H} = \left[\frac{12}{N(N+1)}\sum_{i=1}^{k}\frac{R_{i.}}{n_i}\right] - 3(N+1) \quad (24)$$

where *N* is the total sample size, *n* is the size of the *i*th group, *k* is the number of groups, and $\boldsymbol{R_i}$ is the rank-sum of the *i*th group. Reject $\boldsymbol{H_0}$ when $\boldsymbol{H} > \chi^2_{cp}$ [72].

3. Result and Discussion

3.1. Results

The statistical analysis of the tidal data in Port Klang (Selangor), Bagan Datuk (Perak) and Permatang Sedepa (Selangor) from 2004 until 2017 is shown in Table 1. From this analysis, the average monthly high tide level in Port Klang is 4.4882m, at Datuk Datuk is 2.682m and Permatang Sedepa is 3.977m. Meanwhile, for the monthly low tide level, the average value of Port Klang is 1.459m, in Bagan Datuk is 0.740m and Permatang Sedepa is 1.266. The average tidal level for all three stations is almost the same for 14 years. For the standard deviation value, it gives a small value. This assumes that the data point is close to the mean value.

Table 2: Statistical analysis of tidal data

Station	Tide	Min.	Max.	Mean	Standard deviation
Port Klang	High	4.232	7.524	4.488	0.261
	Low	1.165	2.357	1.459	0.161
Bagan Datuk	High	2.428	3.008	2.628	0.087
	Low	0.579	0.918	0.740	0.081
Permatang Sedepa	High	3.515	4.655	3.977	0.152
	Low	0.826	1.671	1.266	0.146

3.1.1.Pattern or Trend of Sea Level

Figure 2 shows the scatter plot for the monthly average data for all the studies area. Based on the tidal data studied, these three stations show varied tidal patterns or trends. Seasonal tidal patterns show regular pattern in the time series complete on its own within a year and then repeated the following year.

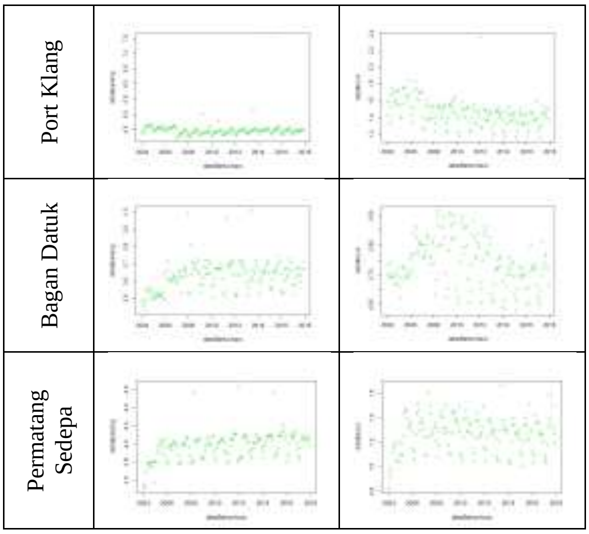


Fig. 2: Scatter plot for high (left) and low (right) tide monthly average data

3.1.2.Non-parametric Mann – Kendall test

Based on Table 3, Port Klang for high tide data, Bagan Datuk and Permatang Sedepa for low tide data shows no significance of monotonic trends since the *p*–value are greater than 0.05 while the other shows that they are having significant monotonic trend. If viewed on the value of τ for both Bagan Datuk (for high tide data) and Permatang Sedepa (for high and low tide data) stations, it gives a positive value which are 0.2449, 0.3545 and 0.0163 respectively. While the other gives negative values of τ.

Table 3: Analysis using Mann-Kendall Test for high and low tide monthly average data

Station	Tide	τ	P – value
Port Klang	High	- 0.0670	0.1977
	Low	- 0.3453	< 0.0001
Bagan Datuk	High	0.2449	< 0.0001
	Low	- 0.1374	0.0083
Permatang Sedepa	High	0.3545	< 0.0001
	Low	0.0163	0.7555

3.1.3.Theil – Sen Trend Line Test

In Table 4, the average monthly high tide data using Theil-Sen Trend Line test, slope values in Bagan Datuk and Permatang Sedepa are 0.0007 and 0.0011 respectively, indicates an increasing trend while the slope value in Port Klang for average monthly of low tide data is -0.0015, indicates a declining trend. Based on the results of the analysis, there are parameters showing significant trends and there are also parameters which do not show a significant trend for each area studied.

Table 4: trend analysis using Theil-Sen trend line test

Station	Tide	slope	CI	
Port Klang	High	- 0.0002	- 0.0004	- 0.0001
	Low	- 0.0015	- 0.0017	- 0.0013
Bagan Datuk	High	0.0007	0.0004	0.0007
	Low	- 0.0004	- 0.0005	- 0.0002
Permatang Sedepa	High	0.0011	0.0009	0.0013
	Low	0.0001	- 0.0001	0.0003

3.1.4.Curve Estimation Model

Table 2 shows significant model for high and low tide data in each station with coefficient of p-value less than 0.05. However, the small R^2 value indicates that all models are inappropriate. Hence, in order to extract exact forecast, a complex model needs to be conducted.

The *p*-value for each term tests the null hypothesis that the coefficient is equal to zero (no effect). A low *p*-value (< 0.05) indicates rejection of the null hypothesis. In other words, a predictor that has a low *p*-value is likely to be a meaningful addition to the model because changes in the predictor's value are related to changes in the response variable.

Conversely, a larger (insignificant) *p*-value suggests that changes in the predictor are not associated with changes in the response.

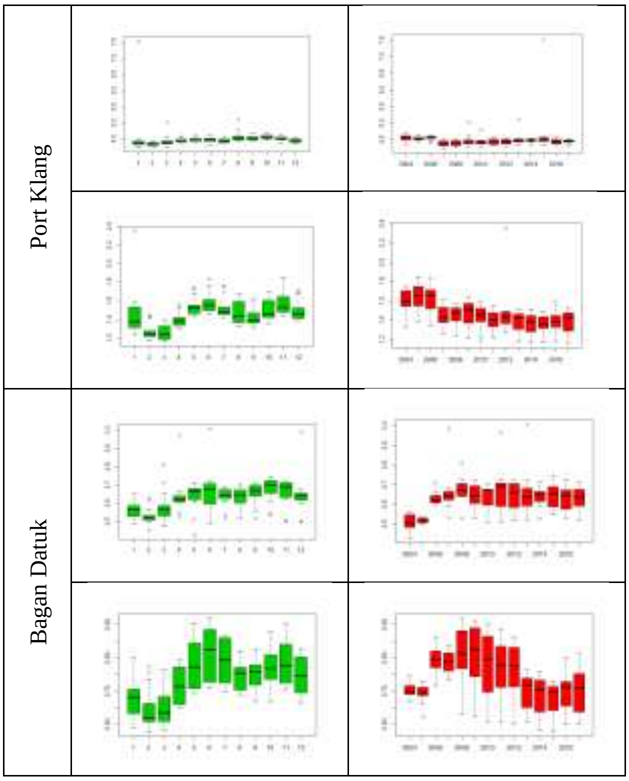
3.1.5. Kruskal Wallis Test

Table 5: Output analysis using the curve estimation model for high and low tide monthly average data

Station	Tide	Model	β_0	P – value	β_1	P – value	β_2	P – value	β_3	P – value	R^2
Port Klang	High	Compound			1.000	.000					.000
	Low	Linear	38.135	.000	-.018	.000					.212
		Logarithmic	280.516	.000	-36.687	.000					.212
		Inverse	-35.239	.000	73798.836	.000					.212

		Quadratic	38.135	.000	-.018	.000					.212
		Cubic	38.135	.000	-.018	.000					.212
		Compound			.988	.000					.218
		Power			-24.642	.000					.218
		Sigmoid (S)	-24.278	.000	49569.639	.000					.219
		Growth	25.007	.000	-.012	.000					.218
		Exponential			-.012	.000					.218
Bagan Datuk	High	Linear	-11.169	.001	.007	.000					.102
		Logarithmic	-102.419	.000	13.810	.000					.102
		Inverse	16.452	.000	-27799.186	.000					.102
		Quadratic	-11.169	.001	.007	.000	.000				.102
		Cubic	-11.169	.001	.007	.000	.000		.000		.102
		Compound			1.003	.000					.108
		Power	1.000E-013		5.341	.000					.108
		Sigmoid (S)	6.312	.000	-10750.470	.000					.108
		Growth	-4.370	.000	.003	.000					.108
		Exponential			.003	.000					.108
	Low	Linear	10.433	.001	-.005	.002					.058
		Logarithmic	74.377	001	-9.681	.002					.058
		Inverse	-8.929	.004	19443.059	.002					.058
		Quadratic	5.593	.000	.000	.002	-1.200E-006				.058
		Cubic	3.979	.000			.		-3.984E-010		.059
		Compound			.993	.000					.060
		Power			-13.368	.001					.060
		Sigmoid (S)	-13.660	.001	26851.204	.001					.060
		Growth	13.077	.002	-.007	.001					.060
		Exponential			-.007	.001					.060
Permatang Sedepa	High	Linear	-28.309	.000	.016	.000					.184
		Logarithmic	-241.729	.000	32.303	.000					.184
		Inverse	36.297	.000	-64992.615	.000					.184
		Quadratic	-28.309	.000	.016	.000					.184
		Cubic	-28.309	.000	.016	.000					.184
		Compound			1.004	.000					.192
		Power	1.000E-013		8.259	.000					.192
		Sigmoid (S)	9.643	.000	-16616.579	.000					.193
		Growth	-6.875	.000	.004	.000					.192
		Exponential			.004	.000					.192
	Low	Compound			1.003	.000					.009
		Power	1.000E-013								.009

In Table 5, *p*-value for all stations for each parameter is less than 0.05 which indicates rejection of the null hypothesis. It can be concluded that the average value of the tested parameters is different.



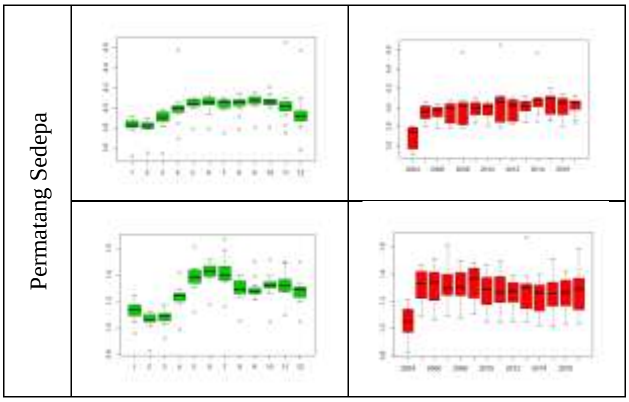


Fig. 3: Boxplot of the monthly average high tide data across month (top left), across year (top right) and monthly average low tide data across month (bottom left), across year (bottom right)

Table 6: Analytical outputs to test the difference among parity equivalents using the Kruskal - Wallis Test for monthly average tidal data

Station	Tide	*H*	*p*-value
Port klang	High	68.192	.000
	Low	49.838	.000
Bagan Datuk	High	82.072	.000
	Low	110.952	.000
Permatang Sedepa	High	54.865	.000
	Low	70.086	.000

3.2 Discussion

Based on the results of the analysis, there are parameters that have the trends and there are also parameters that do not have the trends for each area that have been studied. The studies involving trends for sea level rise are important for early detection to forecast future tides and predict sea level change.

When the results show significant monotonic trends for existing parameters, it can provide a great overview to the researchers to determine and make initial considerations about changes in sea levels in the study area. However, if the parameter does not show any monotonic trend, then a future investigation is needed to know the general flow of parameters over the years [61]. Based on the results of the analysis, the parameter for high tide in Bagan Datuk and Permatang Sedepa showed an upward trend during the study period. The existence of this positive trend may be due to the heat expansion due to the warming of the oceans that took effect from the 1950s [73]. According to [74], the rise in sea levels is due to the dynamic reaction of pressure winds that force or distribute water. In addition, the increase in sea level can also be attributed to the increase in concentration of $\boldsymbol{CO_2}$ in the atmosphere that may be associated with changes in slow wind [75]. On the other hand, for low tide parameters in Port Klang, it shows a downward trend throughout the study period. It is, perhaps influenced by the sea level during high tide in the early decades of the study. Differences trend of tidal sea level, may be linked to climate change has become one the biggest threat to the environment and human in the 21st century. Climate change means the annual temperature of the earth that has risen and drops several degrees Celsius over the past few million years due to the production of heat-trapping gases - mostly carbon dioxide, $\boldsymbol{CO_2}$. The increase of the gas acts as a thick blanket which causes extreme heat to the earth. Temperature records for the past 30 to 50 years has shown an increasing trend in most places including Malaysia [76]. According to [77], the change in mean sea level (MSL) can be considered as a cause for the secular change in tides, arising from the spread of tidal waves controlled by water depths.

Differences trend of tidal sea level might be due to the rainfall. During the rainy season, more water discharges due to the intensity of heavy rain and increasing in the height of the tidal water, this can explain why coastal areas are very vulnerable to flood problems [78]. Due to rising sea levels caused by climate change could force residents to leave low-growing areas [79] where it can result in significant losses.

According to the table 2, all the models are significant, however, all of them have small R^2 values, which indicate that all models used are not appropriate. To get the exact forecast for the study done, a complex model needs to be obtained.

4. Conclusion

This study is related to trend analysis for tidal parameters in Port Klang, Bagan Datuk, and Permatang Sedepa. Understanding the trend of tidal changes is an essential requirement for coastal planning and management. From this study, it gives some insights on the trend pattern in the tidal change parameter in the study location. With this small research effort, it can contribute to understand the trend of tidal change.

Statistical analysis is made as the first step in understanding data. The curve estimation model was used in order to find the best fitting line to represent the trend of the parameter. Mann-Kendall's trend test is the perfect technique to use as it is one of the most widely used techniques for environmental and climate studies. However, the Sen slope detection test has also been used in this study to estimate trends for all parameters of climate change and provide good results such as Mann-Kendall's trend test results. Not much difference from the results shown in both methods. The Sen slope measuring test provides a lower budget value compared to the Mann-Kendall trend test. Overall, Mann-Kendall's tendency test results and Sen's slope detection tests give a good result in tracking the trend of climate change parameters. Both methods can be used in predicting and estimating trends especially for climate change parameters.

In conclusion, the findings from this study provide useful information on the trend of tidal change parameters in Port Klang, Bagan Datuk, and Permatang Sedepa. In addition, the monthly trend analysis for each parameter can also be considered for future analysis.

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