Effects of Hydrological Parameters on Palm Oil Fresh Fruit Bunch Yield)

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Abstract. Climate change effects and variability have been studied by many researchers in diverse geophysical fields. Malaysia produces large volume of palm oil, the effects of climate change on hydrological parameters (rainfall and precipitation) could have adverse effects on palm oil fresh fruit bunch (FFB) production with implications at both local and international market. It is important to understand the effects of climate change on crop yield to adopt new cultivation techniques and guaranteeing food security globally. Based on this background, the paper's objective is to investigate the effects of rainfall and temperature pattern on crop yield (FFB) within five years period (2013 - 2017) at Batu Pahat District. The Man - Kendall rank technique (trend test) and statistical analyses (correlation and regression) were applied to the dataset used for the study. The results reveal that there are variabilities in rainfall and temperature from one month to the other and the statistical analysis reveals that the hydrological parameters have an insignificant effect on crop yield.

1. Introduction

Climate change has become one of the most discussed topics which have attracted the attention of researchers and all stakeholders around the globe. Climate change can be referred to as a change in the climate state identified by variabilities in the mean of its natural characteristics over an extended period say a decade[1]. Similarly, climate change can also be defined as major changes in atmospheric temperature, precipitation pattern and or wind flow occurrence over an extended period[2]. Global surface warming is occurring at a rate of 0.74 ± 0.18 ^{0}C over the past century[3].If this warming continues, future impacts of climate change will be severe. The Intergovernmental Panel on Climate Change (IPCC) reported that there will be a significant reduction in freshwater availability due to changes in climate. It was also projected that by mid-21st-century water availability and annual average runoff will decrease by 30%[4]. There are so many research contributions about climate change for example [5]–[8].

Recent studies affirm that climate change causes variabilities in rainfall and temperature patterns due to increasing rise in amounts of carbon dioxide and other greenhouse gases (GHG) thus, causes disasters such as extreme weather events, drought and flood. Generally, climate change will result to a global rise in temperature and precipitation. Rise in temperature will increase the amount of moisture evaporating from water and ground surface leading to drought in many locations. Flooding and erosion will be renowned in drought-affected locations because such locations are vulnerable during rainfall events. Continues rise in temperature will be associated with more severe and frequent drought across the globe with enormously dangerous consequences for human health, water supply and agriculture[9].

Malaysia is not exempted from climate change variabilities, therefore will experience annual changes such as rising temperature, alteration in rainfall trend which all have impacts on the ecosystem. The contributing factors of climate change in Malaysia can be classified into two: (i) natural processes; rise in population will amount to more consumption and excessive usage of natural resources, and (ii) human activities; industrial activities with usage of large amount of fossil fuels, widespread forest removal, reclaiming more land for agricultural purposes and inadequate government policies toward climate change [10-12].

Since 1972 Malaysia has witnessed rapid growth in palm oil production across all states, with the establishment of commercial plantations that can be attributed to innovation in research and development programs run by the government and industries. However, investigations into effects of climate change on palm oil yield (FFB) is comparatively new with anticipated significant effects. It is apparent that any minor impact on palm oil yield will have enormous social and economic implications on Malaysia and the global market of the commodity[13]. In view of the facts presented above this paper aim to elaborate on the trend of the hydrological parameters (rainfall and temperature) and to evaluate the impact of the hydrological parameters on palm oil yield (FFB).

2. Study area and Methods

2.1 Study Area

The study area is Batu Pahat district in Johor, Malaysia. It lies southeast of Muar, Southwest of Kluang, northwest of Pontian, and South of Segamat on coordinates 1.8499^0 N, 102.9333^0 E (Fig. 1). The average rainfall distribution of the study area is between 2250 – 2600 mm/year[12]. Palm crop yield has been major agricultural produce in Malaysia. Palm plantations around Batu Pahat District were chosen for this study to collect rainfall, temperature data and palm oil fresh fruit bunch yield because of the availability of large hectares covered by palm oil plantation.

Figure 1. Study area

2.2 Data collections
Plantations in Batu Pahat District covers a large area, and the impact of climate change usually involves large areas. Precipitation, temperature and fresh fruit bunch data were collected from relevant agencies and department in Malaysia for a period of 5 years to serve as secondary data. Also, rainfall and temperature logger (U30 weather station) was installed on site to serve as the primary data source and used in this study.

2.3 Methods
According to Chen *et al* [15], both parametric and nonparametric tests can be used for trend detection. Although, in terms of the ability of a test to differentiate between null hypothesis H_o and alternative hypothesis H_1 either Mann- Kendall test for monotonic trends or the Mann – Whitney test for step changes perform well in comparison to the parametric t-test. In this research work, a nonparametric test was used to check the possible trends in hydrological processes. Also, correlation analysis was used to measure the degree of association between the variables while regression technique was employed to examine the relationship between the outcome variable and the confounding factors.

2.3.1 Mann-Kendall rank technique
The Mann-Kendall test is a non-parametric test for identifying trends in time series data. The test compares the relative magnitudes of sample data rather than the data values themselves[16], [17]. The Mann-Kendall test statistic (S) is given mathematically as follows (equation 1.);

$$S = \sum_{k-1}^{n-1} \sum_{j-k+1}^{n} Sign\left(x_j - x_k\right) \tag{1}$$

Where;

$$Sign\left(x_j - x_k\right) = 1 \; if \;\; x_j - x_k > 0$$
$$= 0 \; if \;\; x_j - x_k = 0$$
$$= -1 \; if \;\; x_j - x_k < 0$$

2.3.2 Correlation
Correlation coefficient r, is a measure of the degree of association between crop yield (FFB) and hydrological parameters to check the linear relationship. The correlation relationship guideline for interpretation of positivity or negativity is enumerated in Table 1 while the mathematical expression of correlation is in the form of equation 2.

$$\rho_{x,y} = \frac{\sigma xy}{\sigma x \sigma y} \quad -1 \le \rho_{x,y} \le 1 \tag{2}$$

$$\rho_{x,y} = 0, \; if \;\; x \; and \;\; y \; are \; independent$$

Table 1. Correlation coefficient, r

Range	Relationships
0 ≤ |r| <0.2	Very weak linear relationship
0.2 ≤ |r| <0.4	Weak linear relationship
0.4 ≤ |r| <0.6	Moderate linear relationship
0.6 ≤ |r| <0.8	Strong linear relationship
0.8 ≤ |r| <1.0	Very strong linear relationship

2.3.3 Regression

Multiple regression analysis is one a statistical analysis technique (MLR), it uses a single variable and one or more independent variable. The technique can be used to develop an equation for prediction of the dependent variable based on observed values of the predictors[18]. The technique is widely used prediction of atmospheric values in relation to metrological parameters[19]. In general, multiple linear regression analysis can be mathematically expressed in equation (3).

$$Y_i = \beta_0 + \beta_1 X_{1L} + \beta_2 X_{2L} + \cdots + \beta_P X_{Pi} + \varepsilon_i \tag{3}$$

Where,

Y = Dependent variable

β_0 = Constant coefficients

$\beta_{1,}\beta_2 \ldots \beta_p$ = Regression coefficient of the independent variable X_1, $X_2 \ldots X_p$ (Predictor)

ε = Residual error (difference between observations and predicted values)

Multiple linear regression technique requires the application of two assumptions; Predictor variable must be dependent, the residual error must be independent and have to be normally distributed, with a vanishing mean and a constant variance [20], [21].

3. Results and Discussion

3.1 Pattern of Hydrological parameters

The hydrological parameters considered in this study are mainly rainfall and temperature. The trend of the five years (2013 – 2014) monthly data collected for the study area (Batu Pahat) is shown in figure 2 (Rainfall mm) and figure 3 (Temperature °C). Batu Pahat witnessed a total annual rainfall of 2018.3 mm, 2140.3 mm, 1562.6 mm, 1905.7 mm and 1905.7 mm in the year 2013, 2014, 2015, 2016 and 2017 respectively. The total rainfall recorded in the Batu Pahat over 5 years which was the period considered in this study is 9197.5 mm. The year 2015 has a total annual rainfall of 1562.6 mm which is the minimum while in 2014 a total of 2140.3 mm rainfall event occurred and considered the maximum for the 5 years period.

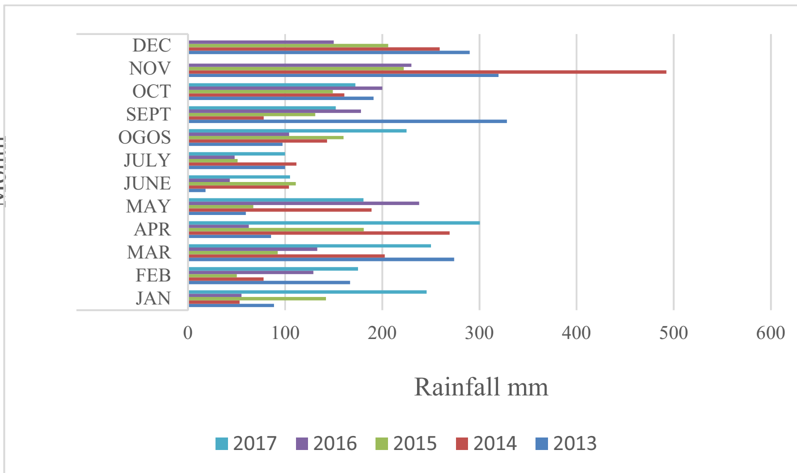

Figure 2. Rainfall Pattern (mm)

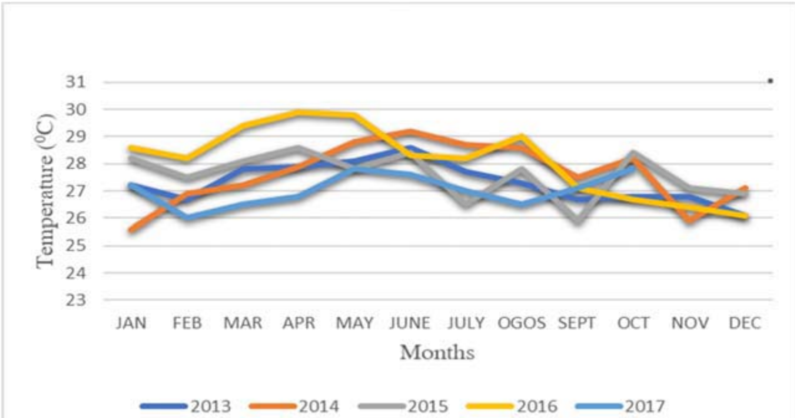

Figure 3. Temperature Pattern (^oC)

Similarly, the average monthly temperature for the study area between 2013 to 2017 as its variabilities with a maximum average of 28.1 ^oC in the year 2016 and the lowest average temperature of 27.3 oC occurs in 2013 which is just slightly below the maximum within the study period. The trend shows a gradual rise in temperature from 2013 to 2017. Mondal *et al* [22] in their study reported that hydrological parameters studies with different time series data have proved that the trend is either increasing or decreasing, both in case of rainfall and temperature. The authors concluded that human interference also leads to climate change with changing land use from the effect of agricultural and irrigation practices

3.2 Fresh fruit bunch yield (FFB)

The monthly crop production yield of plantations around Batu Pahat are presented in Tones/ hectare between 2013 to 2017 (Table 2). Measurement of the FFB produced by the palm tree which is the essential commodity used to produce palm oil was recorded. The records show that the maximum FFB yield was in 2015 with 20 tonnes/hectare produced while in the year 2016 there was a decline in yield to 17.8 tonnes/hectare which is the minimum recorded. The FFB yield was generally characterized by fluctuations over the years in view.

Table 2. Monthly annual FFB yield

Year	**Fresh Fruit Bunch Yield (Tonnes/Hectare)**											
	JAN	FEB	MAR	APR	MAY	JUNE	JULY	OGOS	SEPT	OCT	NOV	DEC
2013	1.55	1.21	1.22	1.33	1.39	1.54	1.78	1.79	2.08	2.04	1.89	1.71
2014	1.51	1.2	1.4	1.44	1.49	1.52	1.72	2.14	1.92	1.91	1.81	1.44
2015	1.17	1.24	1.52	1.78	1.81	1.77	1.87	1.97	1.93	1.9	1.66	1.38
2016	1.09	1.11	1.18	1.25	1.33	1.47	1.54	1.69	1.81	1.8	1.84	1.69
2017	1.4	1.32	1.3	1.34	1.39	1.33	1.82	1.97	2.07	2.28	0.0	0.0

3.3 Mann-Kendal rank trend analysis

Figure 4. is the result of Mann-Kendall test to check the trend in rainfall pattern and the hydrological time series for the study area (13 years). Statistically, this test is run to determine whether the probability

of the values have changes over time (increase or decrease). The trend shows a rising rainfall event from 2004 – 2007 and a decline from 2009 – 2010. The rainfall event of the year 2012 increased while a significant deep was experienced in 2013 and persisted up to 2016

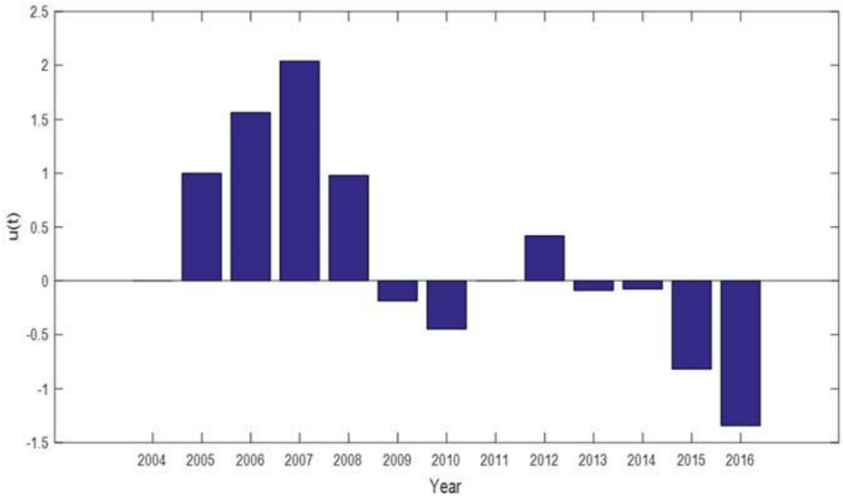

Figure 4. Mann-Kendall rainfall trend test

3.1.4. Correlation and regression analysis

Correlation is a statistical technique used to identify the relationship between the hydrological parameters i.e. rainfall and temperature on the FFB yield. This is to examine the possibility of a relationship between the three variables. Two separate correlation analyses were carried out, FFB yield versus rainfall and FFB yield versus temperature. The correlation coefficient results are as shown in Table 3. The correlation coefficient value between rainfall and FFB yield is 0.122, which is a relatively weak positive linear relationship. This relationship indicates that rainfall has a weak influence on FFB yield, and denotes that an increase in rainfall amount will increase FFB yield. On the other hand, the temperature has a weak negative linear relationship with FFB yield with -0.086 coefficient value. Meaning an inverse proportional relationship i.e. an increase in temperature will cause a decline in FFB yield.

Table 3. Coefficient of correlation

Correlation parameter	**Correlation Coefficient, r**
Rainfall (mm) versus FFB yield (tonnes/hectare)	0.122
Temperature (^{o}C) versus FFB yield (tonnes/hectare)	-0.086

Regression analysis focuses on the estimation of the relationship among the variables namely; rainfall, temperature and crop yield (FFB). This is used to understand the changes in the value of the dependent variable (FFB yield) when any of the two hydrologic parameters value is varied, while one of the independent variables is held fixed. The analysis result is presented in Table 4. Based on the significant values of rainfall and temperature (Table 4) which are higher than 0.05, signifies that the variables (hydrological parameters) do not have any vital influence on the FFB yield. Therefore, other factors such as crop management land use and soil properties may have significant effect on FFB yield.

Table 4. Coefficients of FFB yield, rainfall and temperature

Model		Unstandardized B	Coefficients Std. Error	Standardized coefficients Beta	t	Sig.
1	Constant	2.238	1.135		1.971	.054
	MEAN(Rainfall,1)	.000	.000	.122	.890	.377
	MEAN(Temperature,1)	-.025	.040	-.086	-.628	.533

a. Dependent Variable: MEAN(Yield,1)

In addition, regression analysis was used to deduce an equation for FFB yield for the study area (equation 4). Equation 4. can be used to generate an estimate of FFB yield of a particular period once the average temperature is substituted into the equation.

$$\textbf{Yield} = \mathbf{2.238 - 0.025\ (TEMPERATURE\ ^oC)} \tag{4}$$

4. Conclusion

The trend analysis of the hydrological parameters (rainfall and temperature) of the study area shows staggered fluctuations which may be of help to stakeholders in identifying climate change directions of the study area. However, for proper management purposes to define priorities for planning and implementation of broader national strategies for water and crop yield management and sustainability, it is important to outline the direct effect at the basin level. This study investigates the hydrological parameters effects on FFB yield using Mann- Kendall rank test, correlation analysis and regression techniques. The results illustrate the presence of varied hydrological pattern and displayed the effects of the hydrological parameters trend on crop yield. The rise in temperature over the period or its decline does not have corresponding elevated rainfall amounts and vice versa. Furthermore, the correlation and regression results reveal that rainfall and temperature do not have significant effect on FFB yield. The linear relationship for rainfall on FFB yield is weak even though positive, the temperature has negative linear relationship towards FFB yield. This inverse proportional relationship of temperature to FFB yield means that an increase in temperature of the study area will result to decrease in FFB yield. The study shows that rainfall and temperature trends are not responsible for changes in FFB yield perhaps, other known factors such as soil properties, land use, crop management practice and others may be responsible.

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