Variability and time series trend analysis of rainfall and temperature in Dramaga Sub-District, Bogor, Indonesia

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Abstract: Human-induced climate change is considered a threat to communities and the natural system, in particular, agriculture, forestry, economy, health, and well-being. Explicitly, extreme weather events namely flood and long dry season, are great concerns for Indonesia and the region. The purpose of this study is to detect rainfall and temperature trends in the Sub-district of Dramaga for the past thirty years. Dramaga has a huge number of populations relying on rain-fed agriculture, to feed themselves and support food security. Monthly rainfall and temperature data were obtained from the Dramaga Climatology Station of Meteorology, Climatology, and Geophysics Agency from the period 1990-2019. A Mann-Kendall statistical test has been run to detect the statistical significance of time series in comparison with the linear model. The findings indicated no significant trends in the seasonal and annual rainfall in the past thirty years, whereas, annual mean and maximum temperature are rising significantly. Further, the annual minimum temperature does not show a statistically significant increase. Climate events owing to the rainfall variation and temperature rise threaten smallholder farmers. Results of the study might help decision-makers for climate-smart agricultural projects development at the community level. As to be able, to access environmentally sustainable self-sufficient agriculture.

1. Introduction
Human-induced climate change is assumed to be a concern to the community and, natural system. IPCC in 2014 indicates that more than 50% of the average temperature increase in the period of 1951-2010 was caused by humans. Global warming transforms the water cycle and land ecosystem process [1]. However, temperature rise might not be felt as much as trends in the hydrological process [2]. Particularly, agriculture, forests, economy, human health, and well-being can be influenced negatively through the temperature rise and rainfall variation as the main component of the climate system [3,4]. Future climate projections specify that wet and mid-latitude regions will experience a frequent intensification of rainfall whereas, the subtropical, dry region will see the opposite result [5]. Flood and drought occurrences are correlated to rainfall variability. Nevertheless, drought can lessen in water resources amount including lakes, and dams water level [6,7,8]. While the demand for water supply at the community level is increasing due to overpopulation and humans activities [8]. IPCC confirms that food security will be disturbed due to climate change exclusively in tropical regions in 2014 [5]. Recently, the Indonesian government paid significant attention
to the agriculture sector. FAO stated that the strategic plan of the agriculture ministry 2015-2019, aims to achieve food sovereignty and enhance the welfare of farmers in Indonesia. Since it contributes to Indonesia’s GDP with 10.26 % growth in 2010-2014 [9]. Moreover, it absorbed around 35.76 million laborers approximately 30.20 % of the national labor force in 2014 [10]. 41% of rice fields are located on the island of Java and the majority of the farmers rely on rain-fed agriculture. For instance, 57.3% of farmers in Bogor, West Java utilize rainwater for irrigation purposes [11,12]. Alternatively, Temperature and rainfall pattern trends affect smallholder farmers remarkably, due to their dependences on the natural systems for crop production and feeding communities. Explicitly, rain-fed agriculture-reliant farmers will suffer the most [13].

Indonesia is suffering from huge climate variabilities with its complex topographical characteristic. Owing to the changing climate, natural disasters including extreme weather events such as floods, and long dry seasons threaten Indonesia and millions of peoples in the region. However, high precipitation magnitude can be considered in water availability, agriculture development, food security, and the country’s economy [1,14,15,16]. Every hundred years the temperature in Jakarta is increasing by 1.42°C in July and 1.04°C in January [16]. In addition, climate differences, seasonal variations, and typically rising temperatures lead to water reserve reduction. In Particular, the islands of Java and Bali will receive the risk of floods and drought along with decreasing trend in the dry season and an increased rate of rainfall in the rainy season. A simulation predicts that Bogor city would face water scarcity by 2031 [17]. Water availability depends on annual rainfall rates and land-use changes level. Indonesia Climate Change Sectoral Roadmap ICCSR claimed that 0.5°C temperature rise detected in Indonesia during the 20th century [18].

To predict future climate conditions, and manage water resources for agriculture and other purposes the historical climate data variation must be examined [18,19]. The main purpose of the present study is to detect trends in temperature and rainfall in the period of 1990-2019. This would support the creation of appropriate environmentally friendly sustainable technology and innovation for self-sufficient agriculture and food security.

2. Materials and methods
2.1. Study area
Dramaga Sub-District lies between 06° 35’ 06.0” north latitude and 106° 50’ 08.8” east longitude with an approximately 207-meter elevation above the sea level [20]. Dramaga occupies a 24.37 km² area consist of ten villages [21] (Figure 1). The climate is tropical with rainy and dry seasons. The wet season starts from November to April, and the dry season comprises May to October. The mean annual temperature is estimated at 26.3 °C in 2019 [22]. The majority of households are relying on agricultural activities as their main source of daily income and supporting food security. Rainfall rate plays a significant role in rain-fed agriculture, and the source of drinking water as well.

2.2. Data sources and method
Monthly rainfall and temperature data were collected from Dramaga Climatology Station of Bogor Meteorology, Climatology, and Geophysics Agency BMKG in the period of 1990-2019. Mean temperature is 26.3 °C, maximum temperature is 33.7 ºC, minimum rainfall is 21 °C, and rainfall mean is 3,659 mm. The descriptive statistics such as mean, standards deviation SD and coefficient of variation CV of temperature and rainfall data were computed to analyze the variation and data fluctuation in the period of 1990-2019. A higher CV value determines great variability and a lower CV value shows less variability in the data [22]. The CV is computed using the following statistical formula:

\[ CV = \frac{\sigma}{\mu} \times 100 \]  

Where:
CV = Coefficient of Variation, \( \sigma \) = Standards Deviation, and \( \mu \) = mean.
A simple linear regression model with the coefficient of determination $R^2$ has been run to analyze the trends in the time series of temperature and rainfall data. The regression model statistical formula is given as below:

$$y = aX + b$$

Where:
- $X = \text{time}$,
- $a = \text{slope coefficient}$, and
- $b = \text{least square estimate of the intercept}$.

The slope coefficient determines changes in the unit of time. The positive slope coefficient value indicates an increasing trend and the negative sign shows the decreasing trend in the model [7]. The linear regression model has been run in Microsoft Excel 2019.

The Mann-Kendall test has been computed, to test the trends statistically. The Mann-Kendall’s test known as MK statistical non-parametric test usually has been used for environmental, hydrological, and meteorological time series trend analysis. To run the test, it does not require the data to be normally distributed. According to the MK test null hypothesis indicates that there is no trend in the series and the alternative hypothesis determines that there is a trend in the series [24,25]. To interpret the MK test result, P-value can be compared with the alpha=0.05. The smaller p-value rather than alpha 0.05, reject the null hypothesis $H_0$, whereas the greater p-value rather than alpha 0.05 cannot reject the null hypothesis $H_0$. The MK test statistical formula can be defined as below:

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

Where:
- $\text{sgn}(x_j - x_k) = +1$ (if $x_j - x_k > 0$), $0$ (if $x_j - x_k = 0$) or $-1$ (if $x_j - x_k < 0$).

MK test uses for the time series of n data point and Xj and Xk taken as two subsets of the data [7]. This test is run to a time series of Xk, ranked from $k=1,2,\ldots,n-1$, that is ranked from $j=i+1, i+2,\ldots, n$. Each data point of Xj is derived as a reference point. A higher positive value of S is equal to an increasing trend but a lower negative value identifies a declining trend [25]. Further, Kendall’s Tau value highlights the correlation among variables [4]. The MK test has been computed through XLSTAT 2020 software.
3. Results and discussion

3.1. Precipitation

According to the obtained data, the Dramaga sub-district has experienced an annual mean rainfall of 3878 mm in the past 30 years. Where descriptive statistics table 1 reveals the monthly average rainfall of 1990-2019 with a huge variation. The month of July indicates the lowest and November the highest mean rainfall of 193 mm and 439 mm, respectively. The rainy season starts from November until April, where the dry season comprises six months from May until October each year. May and August’s months have the lowest and highest extent of rainfall fluctuation with 31.72 and 73.92 coefficient of variation, respectively. Figure 2 describes the rainfall pattern for the last three decades. Rainfall decline can be seen in March, April, and May in the last decade (2010-2019), While the first decade (1990-1999) determines a high precipitation rate in March and April. Meanwhile, the rainfall rate in November has the highest rate in the last decade. The computed time series trend analysis of rainfall through linear regression in Figure 3 shows a decreasing trend during the wet season with a negative regression slope value of 11.117. Simultaneously dry season time series regression model in Figure 4 explains a decreasing rainfall of 4.9313 mm by an increase of each time period but, the dry season decrease trend is less significant in comparison with the wet season. Overall annual mean rainfall with the regression slope of -13.441 in Figure 5 indicates a decreasing trend through an increase of each time period of 1990-2019.

Table 1. Descriptive statistical summary of monthly mean rainfall (1990-2019).

| Variable | Observations (Year) | Minimum | Maximum | Mean | Std. deviation | Coefficient of Variation CV(%) |
|----------|----------------------|---------|---------|------|----------------|------------------------------|
| Jan      | 30                   | 133     | 704     | 386  | 146.4          | 37.91                        |
| Feb      | 30                   | 86      | 612     | 384  | 123.9          | 32.24                        |
| Mar      | 30                   | 99      | 744     | 351  | 168.3          | 47.96                        |
| Apr      | 30                   | 43      | 669     | 398  | 156.7          | 39.41                        |
| May      | 30                   | 118     | 571     | 352  | 111.7          | 31.72                        |
| Jun      | 30                   | 51      | 686     | 246  | 139.3          | 56.63                        |
| Jul      | 30                   | 2       | 404     | 193  | 123.1          | 63.73                        |
| Aug      | 30                   | 10      | 647     | 210  | 154.9          | 73.92                        |
| Sep      | 30                   | 22      | 603     | 251  | 144.9          | 57.64                        |
| Oct      | 30                   | 111     | 584     | 351  | 129.4          | 36.84                        |
| Nov      | 30                   | 179     | 855     | 439  | 161.3          | 36.74                        |
| Dec      | 30                   | 72      | 583     | 317  | 131.1          | 41.43                        |

The MK test has been computed as a comparison with the linear regression model to the obtained rainfall data in the time period of 1990-2019. Table 2 explains the MK statistical test summary with the 5% significance level. The conducted MK test indicates no trends in the annual, wet, and dry season rainfall series. As the computed P-value for the annual, wet, and dry season rainfall is 0.143, 0.239, and 0.372, respectively, which represent the greater P-Value rather than significance level alpha = 0.05 hence, it fails to reject the null hypothesis.
Table 2. Mann-Kendall’s statistical test summary for the seasonal and annual mean rainfall (1990-2019).

| Variable                | Kendall's tau | MK Test Statistic (S) | Var (S)    | p-value (Two-tailed) | Alpha | Std. deviation | Mean     |
|-------------------------|---------------|-----------------------|------------|----------------------|-------|----------------|----------|
| Annual Rainfall         | -0.191        | -83.000               | 3,141.667  | 0.143                | 0.05  | 563.3          | 3,877.5  |
| Wet Season Rainfall     | -0.154        | -67.000               | 3,141.667  | 0.239                | 0.05  | 427.554        | 2274.2   |
| Dry Season Rainfall     | -0.117        | -51.000               | 3,141.667  | 0.372                | 0.05  | 458.892        | 1,603.2  |

3.2. Temperature

Temperature variability in table 3 shows the high fluctuation in January and less in August with the 1.9452 and 1.2049 coefficient of variation, respectively. Based on average temperature February and May are the coldest and warmest months in the time period of 1990-2019 with the 25.21 and 26.21 mean, respectively. The last ten years (2010-2019) counted as the warmest decade in the past 30 years. These ten years experienced warmer weather conditions in April and May months with the 27.1 centigrade mean temperature in the last 30 years. Meanwhile, the second decade (2000-2009) average temperature from January until June was colder in comparison with the first and third decade. The
month February average temperature in 2000-2009 with 25.5 centigrade can be considered the coldest month among others in the past three decades. The computed simple linear regression trend model for annual mean temperature data display an increasing trend with the regression slope value of 0.0251 and 0.3555 $R^2$ value (Error! Reference source not found.). At the same time, the annual maximum (Error! Reference source not found.) and minimum temperature (Error! Reference source not found.) show an increasing trend with the 0.0378, 0.0226 regression slope value and 0.2401 and 0.0873 $R^2$ value, respectively.

Table 3. Descriptive statistical summary of monthly mean temperature (1990-2019).

| Variable | Observations | Minimum | Maximum | Mean | Std. deviation | CV % |
|----------|--------------|---------|---------|------|----------------|------|
| Jan      | 30           | 24.500  | 26.400  | 25.327 | 0.493           | 1.9452 |
| Feb      | 30           | 24.400  | 25.900  | 25.210 | 0.405           | 1.6082 |
| Mar      | 30           | 24.900  | 26.400  | 25.667 | 0.346           | 1.3471 |
| Apr      | 30           | 25.400  | 27.100  | 26.047 | 0.441           | 1.6923 |
| May      | 30           | 25.300  | 27.100  | 26.210 | 0.397           | 1.5141 |
| Jun      | 30           | 25.300  | 26.500  | 25.843 | 0.322           | 1.2474 |
| Jul      | 30           | 24.900  | 26.100  | 25.593 | 0.338           | 1.3218 |
| Aug      | 30           | 25.200  | 26.300  | 25.660 | 0.309           | 1.2049 |
| Sep      | 30           | 25.300  | 26.600  | 25.907 | 0.330           | 1.2739 |
| Oct      | 30           | 25.100  | 26.800  | 26.077 | 0.442           | 1.6962 |
| Nov      | 30           | 24.900  | 26.900  | 25.967 | 0.411           | 1.5841 |
| Dec      | 30           | 24.800  | 26.300  | 25.707 | 0.396           | 1.5423 |

To find out statistical significance and comparison with the linear regression model, the MK statistical test has been run for the obtained data of annual mean, maximum, and minimum temperature data in the period of 1990-2019. Error! Reference source not found. explains Mann-Kendall’s test summary that indicates increasing trends in the annual mean and annual maximum temperature. The P-value for the annual mean and maximum temperature are 0.001 and 0.006 which are smaller than alpha 0.05. Therefore, it rejects the null hypothesis $H_0$. Meantime, the P-value of annual minimum temperature is 0.378 and greater than alpha $=0.05$ that, which fails to reject the null hypotheses $H_0$ and hence, no trend detected in the annual minimum temperature series.

Table 4. Mann-Kendall’s statistical test summary of temperature (1990-2019).

| Variable                        | Kendall's tau | MK Test Statistic (S) | Var(S) | p-value (Two-tailed) | alpha | Std. deviation | Mean |
|--------------------------------|---------------|-----------------------|--------|----------------------|-------|----------------|------|
| Annual mean temperature        | 0.454         | 190.000               | 3094.000 | 0.001                | 0.05  | 0.370          | 26.443 |
| Annual maximum temperature     | 0.365         | 154.000               | 3107.333 | 0.006                | 0.05  | 0.678          | 32.983 |
| Annual minimum temperature     | 0.119         | 50.000                | 3095.333 | 0.378                | 0.05  | 0.674          | 21.447 |
Figure 6. Monthly mean temperature pattern of the last three decades.

Figure 7. Linear regression slope of the annual mean temperature (1990-2019).

Figure 8. Linear regression slope of annual maximum temperature (1990-2019).

Figure 9. Linear Regression slope of annual minimum temperature (1990-2019).

4. Discussion
Annual precipitation rates play a significant role in the agriculture sector particularly, where farmers rely on rain-fed agriculture. Monthly average rainfall data shows great variation in the past three decades. Whereas unpredictable rainfall and variation may cause several natural hazards such as floods and landslides. Recently, continuous and heavy rainfall, affected 409,000 people through flooding in Jakarta, Bogor, and surrounded regions in January 2020 [26]. However, there is a decreasing trend in the annual and seasonal rainfall explained by the linear regression equation. But, statistically, the MK test result reveals no significant trend in the annual and seasonal rainfall in the Dramaga area in the time period of 1990-2019. This finding is not similar to Indonesia’s national historical climate data that shows an increasing trend of 12% precipitation in the country level from 1985-2015 [27]. Local topography, altitude, and slope are significantly correlated with the annual mean rainfall [28]. Geographical characteristics such as elevation, topographical variation, and mountains in Bogor consist of the lowest 107 m until the highest 789 m above the sea level [21] can be considered as the main factor affecting rainfall variation in Bogor Regency.

Climate variability particularly temperature rise concern is a global phenomenon. Warming is happening in the earth’s atmosphere. Linear regression slope determines significant correlations with the MK statistical test result for the annual mean and maximum temperature except for the annual minimum temperature. These findings are similar to the IPCC report where they listed 1983-2012 as the warmest years in the earth’s history [5].

5. Conclusion
Indonesia faces greater climatic challenges containing temperature rise and rainfall variation [16]. We observed rainfall variability with the lowest and highest fluctuation in July and November, respectively. Since the rainy season begins in November until April. The present study has been proven that there
are no significant trends statistically in annual, and seasonal mean rainfall in the period of 1990-2019. Although the linear model of annual, and seasonal rainfall displays great variation along with a slight decline since 1990. Significant increasing trends have been detected for the annual mean, and maximum temperature except for the annual minimum temperature. Further, the both linear model and MK statistical test of annual mean, and maximum temperature comply with each other. Climate extreme events owing to the rainfall variation and temperature rise affect local communities, and smallholder farmers. Hence, based on the study findings, decision-makers may develop climate-smart agricultural projects at the community level. This would support the creation of appropriate environmentally sustainable self-sufficient agriculture.

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