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Statistical Analysis of 30 Year Rainfall Data: A Case Study for Langat River Basin

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Abstract: Rainfall is an important factor in civil engineering as it affects the design of hydraulic structures, bridges and culverts, canals, storm water sewers, road drainage systems, etc. This paper presents the statistical analysis of 30-year rainfall data collected at eight rainfall stations within the Langat River Basin. Ten plotting position methods were utilised to evaluate the return period of annual rainfall. The yearly rainfall was computed to assess the variability of rainfall based on the determined results; the pattern of rainfall is irregular. Weibull Distribution from Plotting Position methods is found to best fit the annual rainfall data. The findings provide the insights for determining the correct commencement and cessation of monsoon results, which have the effect on land utilisation, flood forecasting and emergency planning. This analysis contributes to water management, water resource planners, farmers, and urban engineers to evaluate the availability of water and develop the storage accordingly.

Keywords: Weibull distribution, Rainfall, Precipitation, Langat river basin, Plotting position.

Introduction

Water is essential to all life. Water is also used for transportation, as energy source, and for a number of additional domestic, agricultural, and industrial purposes. Rainfall is the most important source of water in any location, and it has a huge effect on agriculture (Rosegrant et al., 2009; Abdullah & Rahman,2015). Malaysia has distinct rainfall patterns and features compared to the rest of the globe. It has two distinct monsoon seasons, the South-East Monsoon (SEM) from May to September and the North-West Monsoon (NWM) from November to February. In recent years, the rapid change in climate has increased the number of severe floods in Malaysia. In the floods of December 2021, the calamity has taken almost 50 lives and displaced more than 40000 people, while the economic losses caused by the particular event was around USD1.46 billion (Rahman, 2022). Consitent with the rising of atmospheric temperatures and water vapour, the frequency of extreme rainfall occurences have increased in most land areas around the globe (Amirabadizadeh et al., 2015; Solomon, 2007). The study of rainfall mechanisms such as rainfall distribution estimation and characterization of rainfall types, rainy or dry conditions on a given day,is important for use in water resources planning and flood management. For agriculture sector, itis essential to assess the probability of rainfall occurrence using historical hydrological data sets, as agricultural output is dependent on the rainfall pattern, particularly in rain-fed areas (Maraun et al., 2010).

Suchit Kumar Rai et al. (2014) examined the change, variability, and likelihood of rainfall for crop planning in a few areas in Central India. *Student's t* was used to construct the probability distribution of rainfall, while Mann-Kendall rand statistic, Spearman rank statistic, and Gaussion low-pass were employed to examine the rainfall trend. The study concluded that the rainfall probability projections are consistent with the historical records. Nyatuame et al. (2014) conducted a study on rainfall trend for Volta Region in Ghana. Analysis of Variance (ANOVA) and Least Significant Difference (LSD) were used to analyse the rainfall data recorded over the period of 1981 to 2011. The study concluded that climate change does not affect the monthly and annual rainfall trends in the region. However, other rainfall characteristics such as extreme rainfall, rain days, and other climate change paramenters were not investigated. Rajendran et al. (2016) conducted a frequency analysis of rainy days and a rainfall fluctuation study for crop planning in Dharmapuri district in India. Markov Chain model was used to analyse the daily rainfall data from 1982 to 2013 for identifying the appropriate cropping systems in the region, while Weibull distribution was employed to compute the probability of occurence of each event. Linear regression was employed to study the relationship between the rainfall amount and rainy days. The authors concluded that the weekly, monthly, seasonal, and annual rainfall patterns and frequencies can be used as a rough guide for irrigation planning and management, as well as contingent crop planning during drought periods. Tan et al. (2019) studied rainfall trends and temperature extremes of Muda River Basin in Malaysia using historical daily climate data from 1985 to 2015. Homogeneity tests were employed to compute the Expert Team on Climate Change Detection and Indices (ETCCDI), while Non-parametric Mann-Kendall, modified Mann-Kendall, and Sen's slope tests were used to detect the trend and magnitude changes of the climate extremes. The work reveals that monthly rainfall tended to decrease in the SWM season, but increase in the NEM season, with increasing number of warmer days and nights in the basin.

This study presents the statistical analysis of 30-year rainfall data collected at eight rainfall stations within the Langat River Basin. Frequency or probability distribution is used to link the intensity of extreme occurrences, such as floods, droughts, and severe storms, to their frequency of occurrence, so that their probability of happening over time can be predicted. By fitting a frequency distribution to a set of hydrological data, the probability of occurrences may be computed. The hydrological data are evaluated in order to fit the distribution, and statistical parameters are utilised to analyse the data's variability.

Study Area

Figure 1. Langat river basin

This study focuses on the Langat river basin in Selangor, Malaysia, which has a total catchment area of 2,271 km^2. Located in the southern portion of Klang Valley, the Langat River Basin (Figure 1) is the most urbanised river basin in Malaysia. This basin is drained by the Langat River, the Semenyih River, and the Labu River.

Langat River runs roughly 182 kilometres west to the Straits of Malacca from Titiwangsa Range (Banjaran Titiwangsa) northeast of Hulu Langat (Soo et al., 2020). This study region includes two reservoirs, namely Langat dam and Semenyih dam. There are now eight water treatment facilities functioning in Langat Basin. Up till the Kajang observation station, the rainfall station analysis is located in the Upper Part of Langat River Basin (UPLRB) (Ali et al., 2014; Khalid et al., 2016; Faiza et al., 2022).

Method

The main focus of this paper is to identify the most suitable plotting position method for rainfall data in UPLRB. The rainfall data from 8 stations within the UPLRB catchment was provided by the Department of Irrigation and Drainage (DID) in Ampang within and outside the Langat River Basin. The daily rainfall at each station was then aggregated to calculate the total seasonal and the total annual data series. The analysis has been carried out for 30 years return period only. Mean rainfall for the annual and th seasonal rainfall has been determined. The plotting position methods to fit the rainfall data (Khalid et al., 2016) and details of the plotting methods are presented in Tables 1 and 2, respectively.

Table 1. Plotting position methods

No	Plotting Position	Equation
1	Adamowski	(m-1/4)/(N+1/2)
2	Beard	(m0.31)/(N+0.38)
3	Blom	(m-3/8)(N+1/4)
4	California	m/N
5	Chegodayev	(m-0.3)/(N+0.4)
6	Cunnane	(m-0.4)/(N+0.2)
7	Gringorten	(m0.44)/(N+0.12)
8	Hazen	(m-0.5)/N
9	Tukey	(3m-1)/(3N+1)
10	Weibull	m/(N+1)

Where, m is rank of the data and N = length of the sample (number of years).

Result and Discussion

Using statistical criteria, the yearly rainfall data is evaluated and the variance in distribution over the area is studied. The monthly and seasonal trends of the rainfall distribution are also investigated.. The rainfall data is arranged in decreasing order, and several plotting positions are used to establish the return period. Using the rainfall-return period equation derived from the graph for all plotting positions, the rainfall magnitudes for different return periods were determined as shown in Table 2 and Figure 2.

Table 2. Maximum Annual Rainfall based on Plotting Position Methods

Method/Return period	5	10	15	20	25	30
Adamowski	1311.759	1406.633	1510.259	1561.15484	1606.800612	1652.446
Beard	1297.716	1369.564	1467.65	1527.603278	1553.894763	1580.186
Blom	1311.759	1406.633	1510.259	1561.15484	1606.800612	1652.446
California	1311.759	1406.633	1510.259	1561.15484	1606.800612	1652.446
Chegodayev	1297.923	1370.341	1468.623	1528.275348	1555.088605	1581.902
Cunnane	1295.876	1362.743	1459.224	1522.250598	1544.02012	1565.790
Gringorten	1295.069	1359.811	1455.668	1520.277351	1540.138542	1560.00
Hazen	1293.871	1355.529	1450.554	1511.894921	1534.908522	1552.026
Tukey	1297.236	1367.766	1465.41	1526.095003	1551.183991	1576.273
Weibull	1304.306	1395.36	1501.058	1555.449119	1599.66846	1643.888
Average Max Rainfall	1301.727	1380.101	1479.896	1537.531014	1569.930484	1601.74

According to the preliminary investigation and analysis, the difference in maximum annual rainfall for different plotting positions is insignificant. For UPLRB, the Adamwoski plotting approach produces the highest value for rainfall for varied return periods, while the Hazen method produces the lowest value and is therefore deemed inapplicable for use in rainfall analysis. In contrast to other plotting positions, Weibull method yields a maximum rainfall that is around 95% of the average maximum rainfall, and is thus the most suitable distribution for describing the yearly rainfall data for UPLRB. It can be observed from the tabulated result for 5, 10,15, 20,25 and 30 years (see Table 2), Weibull method provides the most consistent result in comparison to the average maximum rainfall given. It is also observed that the amount of rainfall increases with return period, consistent with the findings reported by Amırabadızadeh (2015) and Loo et al. (2015).

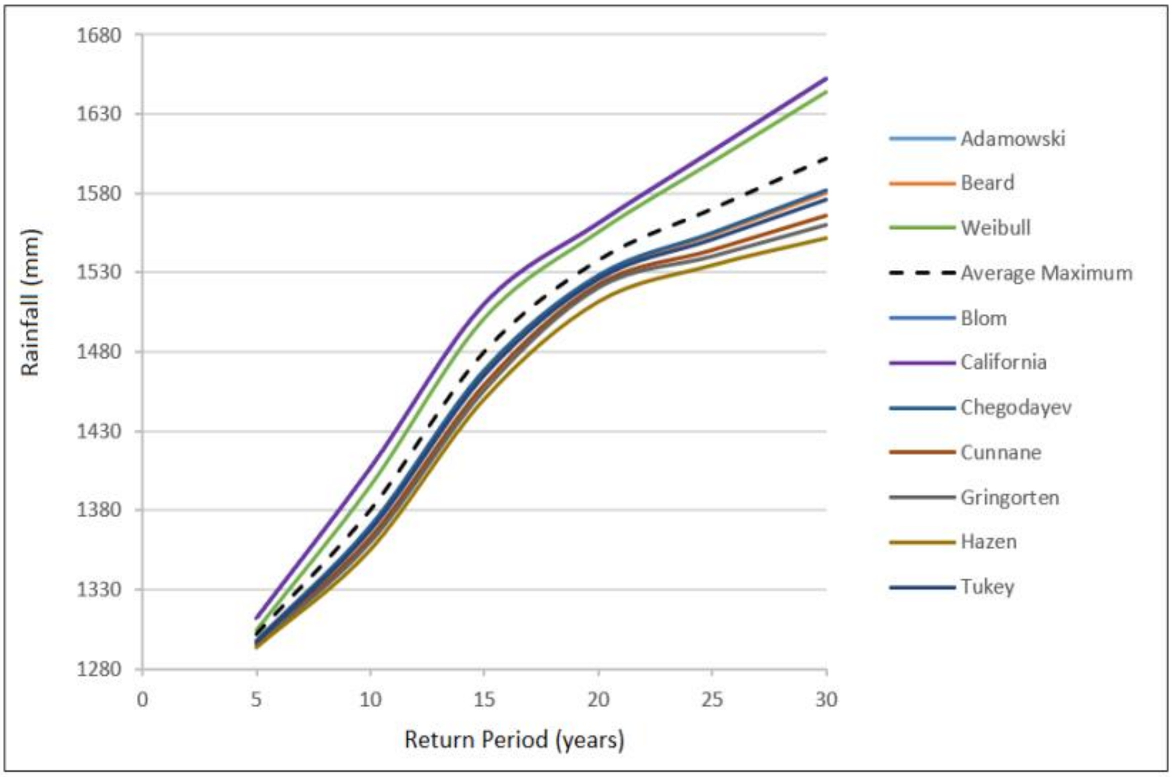

Figure 2. Plotting position

The transition between the NEM and SWM (and vice versa) in April and October is known as the inter monsoon season, which lasts between four and seven weeks (Arvind et al., 2017; Toh et al., 2013). Table 3 tabulated the average monthly rainfall and illustrated in Figure 3. The highest rainfall recorded was in November with 315.17 mm and the least amount of rainfall recorded is 113.39 mm. The mean average rainfall recorded for 12 months is a round 202.24 mm. It can be observed that January, June and July are the driest months in a year.The record shows that NEM has 9.3% higher rainfall compared to SWM. The inter-monsoon seasons have higher amount of rainfall, about 258.69 mm in April and 251.85 mm in October, respectively. Figure 4 shows the average seasonal rainfall in UPLRB.

Table 3. Average monthly rainfall in UPLRB (DID, 2014e)

Month	Average Rainfall, mm
January	113.39
February	159.88
March	225.77
April	258.69
May	208.53
June	143.89
July	150.07
August	180.35
September	228.86
October	251.85
November	315.17
December	190.47
Grand Average	202.24

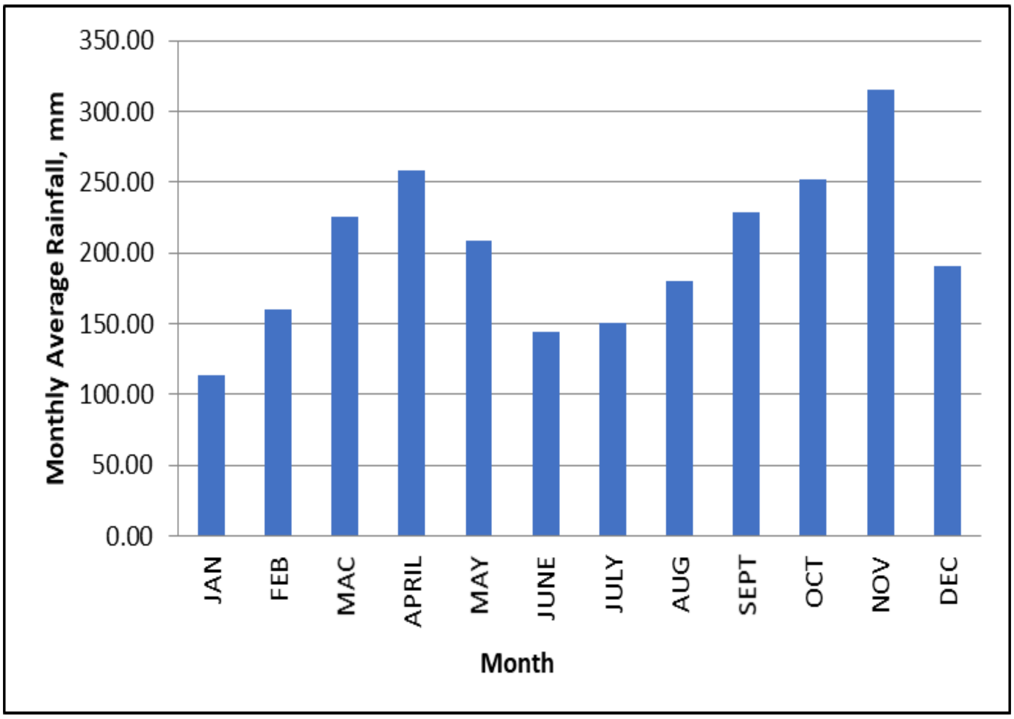

Figure 3. Bar chart of average monthly rainfall in UPLRB (DID, 2014e)

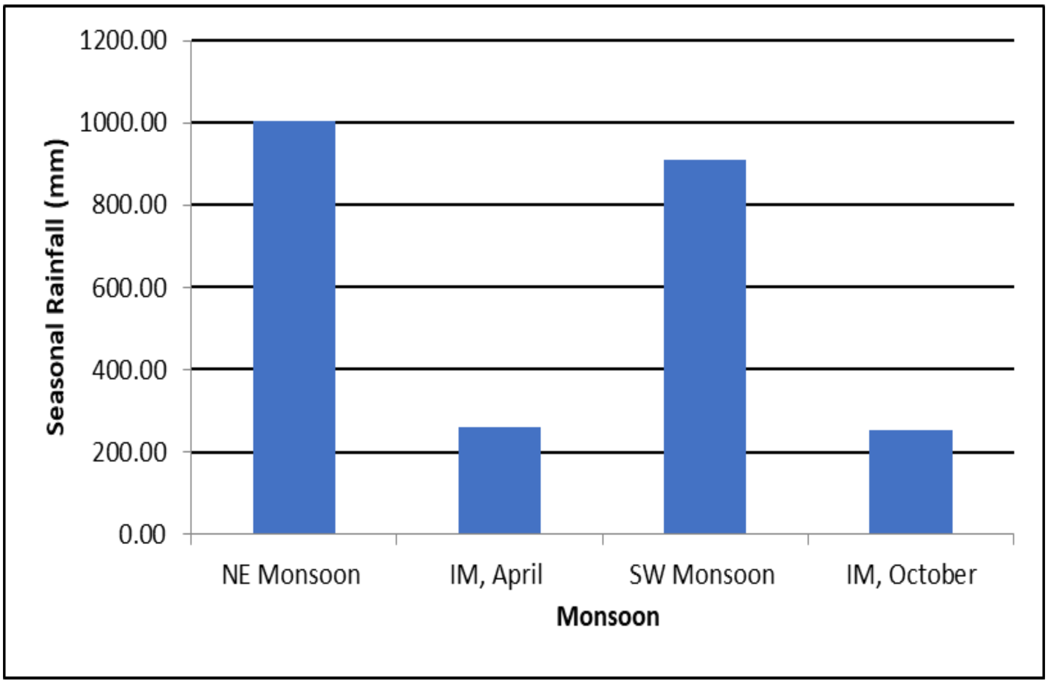

Figure 4. Average seasonal rainfall in UPLRB (DID, 2014e)

Conclusion and Recommendations

This is a preliminary data analysis for rainfall data distribution before comprehensive data analysis to be conducted. This analysis helps in understanding the rainfall pattern within the Langat River Basin. Weibull Distribution is found to best fit the annual rainfall data. It can be observed that the rainfall amount increases with return period. According to the preliminary investigation and analysis, the variance of different plotting position is insignificant. All the data are independent, stationary and homogenous. The analysis can be used to aid the policy maker to understand the conjunctive use of surface water, available rainfall, and ground water is for improved agricultural and irrigation management.

Scientific Ethics Declaration

The authors declare that the scientific ethical and legal responsibility of this article published in EPSTEM journal belongs to the authors.

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