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FLOOD RISK PATTERN RECOGNITION IN KINABATANGAN RIVER, SABAH

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ABSTRACT

A flood can be described as any high-water flow in any part of the river system which dominates the natural or artificial banks. In Malaysia, floods frequently occur because of the increase in rainfall rates and rising sea levels in certain parts of the country. This study was conducted to determine the flood risk pattern recognition in Kinabatangan River, Sabah. Thirty years (1989-2019) secondary database obtained from the Malaysian Department of Irrigation and Drainage (DID) Ampang, Kuala Lumpur was statistically analysed using chemometrics techniques. The finding demonstrated that only water level with strong factor loadings (44.82 %) was classified as the most potential contributors of flood occurrence in the research region as it had a good consistency compared to other variables, rainfall and evaporation. From the results, 99% out of total result being classified as High Risk Class with a range of 70 and above risk index, 1% classified as a Cautionary Zone Class with a risk index from 37.14, meanwhile 0% fall into Low Risk Class with a risk index from 0-34. This shown that Kinabatangan River was prone to flood phenomenon. In short, the flood risk index model developed would be a very useful resource for flood mapping and future hazard or risk management prediction, with the engagement of both public and private sectors being key to effective floodplain management.

INTRODUCTION

Over the last three decades, flooding has been a major risk in the world and nowadays is becoming more common in Malaysia. It has caused the loss of lives and property destruction (Kourgialas & Karatzas, 2011). Specifically, there are two categories of flooding that usually take place in Malaysia which are monsoon flood and flash flood. Monsoon flood normally happens around May until August, which is called as Southwest Monsoon, and around November until February is called Northeast Monsoon (Tan et al., 2013). In contrast, flash floods usually occur in a busy city. It was caused by the uncontrolled human activities, such as the development of infrastructure near river areas and uncontrolled littering causing obstructed drains and waterways (Sipon et al., 2015). As for the year 2000, the estimated flood-prone region is approximately 29,800 km2 or 9% of the total Malaysia area and is affecting almost 4.82 million people, about 22% of the country's total population (Zakaria et al., 2017). Throughout Malaysia, including Sabah and Sarawak, there are a total of 189 river basins flowing directly to the South China Sea, which 85 of them are vulnerable to recurrent flooding, 89 of the river basins are in Peninsular Malaysia, 78 in Sabah and 22 in Sarawak region (D/iya et al., 2014). In particular, average mean rainfall in Sabah is about 2,600mm and it is the largest state of Malaysia with a surface area about 73,631 km2 and a population of around 3,117,405 people (DID, 2010). Sabah is a state enriched with the natural nature but it is also one of the floods frequently occurring. Area of Kinabatangan, Sabah was regarded as major flooding that occurred due to human error in terms of infrastructure growth and the region also exposed to flood events in which the basin receives a high amount of rainfall that can cause the basin to overflow to the surrounding area (Roslee et al., 2017).

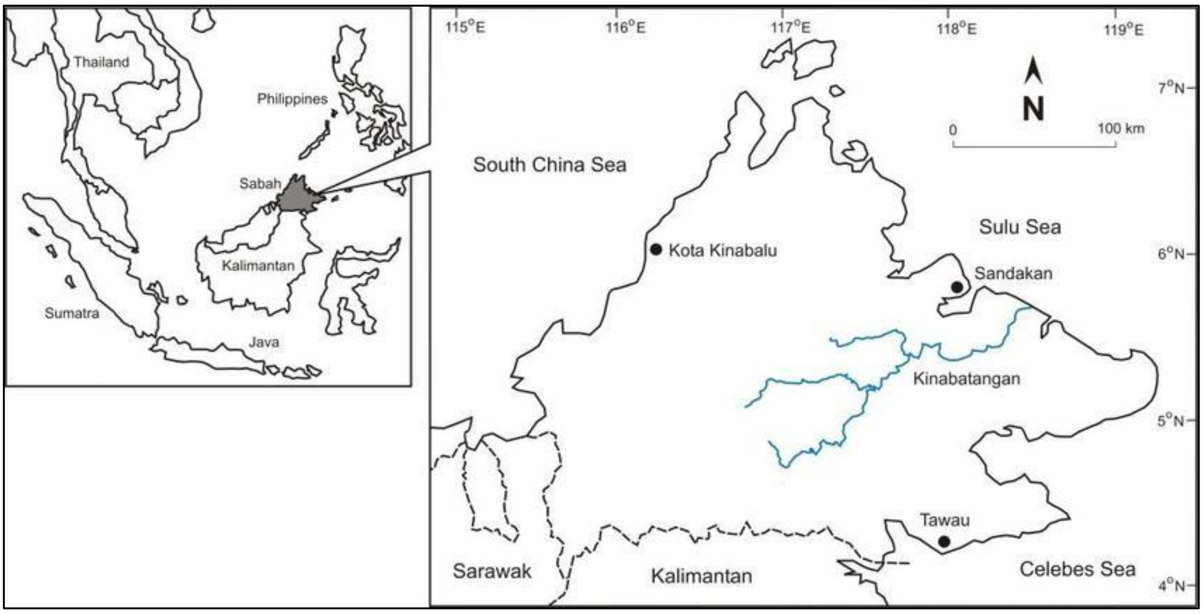
METHODOLOGY

Study Design

This study applied multivariate analytical analysis using the chemometrics techniques to analyse a set database of flood parameters based on the multivariate statistical principles. This study designated primarily to identify the trend of flood risk in Kinabatangan River, Sabah.

Study Area

The Kinabatangan River is the largest and longest in Sabah, Malaysia. Kinabatangan River is a significant proportion of water suppliers to Sandakan, Sabah's second-largest urban centre for people living in village within Kinabatangan River such as Balat, Barek Manis, Bukit Garam and Tangkulap. The total population living in Kinabatangan Town is around 86,783 people. As in Figure 1, Kinabatangan River with 560 km is the largest river situated at the latitude of 5° 18' 35" N and longitude of 117° 35' 50" E, with 16,800 km^2 of the catchment area is a part of Kinabatangan River, Sabah. The elevation of the study area is 23 meters and it occupies almost 23% of Sabah's total land area and the annual mean rainfall in the basin around 2,300 mm to 3,000 mm per year (Roslee et al., 2017).



Sources: (Roslee et al., 2017)
Figure 1: Maps of Kinabatangan River, Sabah

Data Collection

Thirty years of hydrological data on Kinabatangan River, Sabah from 1989 to 2019, which contained 777,600 of the total data including 3 (variables) × 24(hours) × 30(days) × 12(months) was obtained from the DID to be applied in the study. The data collected by the qualified DID officer comprises of three parameters which were rainfall, water level and evaporation. The measurement for these variables was recorded daily.

Data Analysis

All the data in this study were analysed by using XLSTAT software for integrated chemometrics technique comprises of Principal Component Analysis (PCA), Statistical Process Control (SPC) and Flood Risk Index (FRI). PCA was applied to define a large number of variables into the smaller sets. It also reduced the number of variables, and examined the structure or relationship between variables (Saudi et al.,2015). Afterwards, SPC would produce three important results, which were important in predicting the hydrological modelling in the future, and those results were Upper Control Limit (UCL), Average Value (AVG) and Lower Control Limit (LCL). The Sigma in the control chart was represented as within the range value of a set of data. The Control Chart had the potential to uncover some trends and patterns, showing actual data deviations from the historical baseline and dynamic threshold, having the ability to capture unusual resource usage and becoming the best baseline to show how actual data had deviated from the historical baseline (Saudi et al., 2018). Followed by the FRI, the formation of UCL value would ready to provide a guideline in determining the ratio of the FRI for the study area. The UCL value was considered as the intolerable value for a variable and treated as a high-risk condition for flood (Saudi et al., 2017).

RESULTS AND DISCUSSION

Normality Test

The data of three parameters (water level, rainfall and evaporation) that contribute to flood in Kinabatangan River, Sabah were being analysed by using the normality test (Anderson-Darling). The result of normality test of computed p-value was lower than the significance level alpha=0.05. Thus, the test indicated that the data was not normally distributed with a result of the p-value (<0.001).

Identifying the most sensitive parameters that contribute to the flood occurrence

After varimax rotation, two varifactors (VFs) or factor loadings were obtained which represented the 73.78% of the cumulative variance of the data. Table 1 highlighted the findings of factor loadings after varimax rotation. The total variance in the first factor loading (VF1) was about 44.82 % with strong positive factor loadings for water level (0.704) and also a moderate negative factor loading on evaporation (-0.610). Moreover, the second factor loading (VF2) accounts for 28.96% of the total variance with one strong positive factor loadings on evaporation (0.789). In this study, only factor loadings greater than 0.70 (>0.70) were selected for interpretation as these values were considered as stable and strong loadings.

Table 1: Factor loading after varimax rotation

Variables	VF1	VF2
Water Level (m)	**0.704**	0.284
Rainfall (mm)	0.690	0.408
Evaporation (mm)	-0.610	**0.789**

Note: Bold = Factor loading > 0.70

Hence, according to Figure 2, only water level with strong factor loadings in VF1 (44.82 %) were selected for further analysis as it had a good consistency. This variable was classified as the most potential contributors of flood occurrence in Kinabatangan River, Sabah. The results were supported by the previous study stated that lower reaches of the Kinabatangan River were heavily influenced by rainfall, which was continuously present during the flood season, and caused a higher rate of water levels. When the water level increased above the riverbanks or dams, the water started to overflow, hence caused river-based floods. The water runoffs to the areas attached to the rivers or dams, triggering floods (Harun, 2013). Consequently, it was crucial that hydrologists give more attention to the increased frequency of flooding to demarcate the contributing factor of rainfall-induced runoff and high level of water (Lee, 2014).

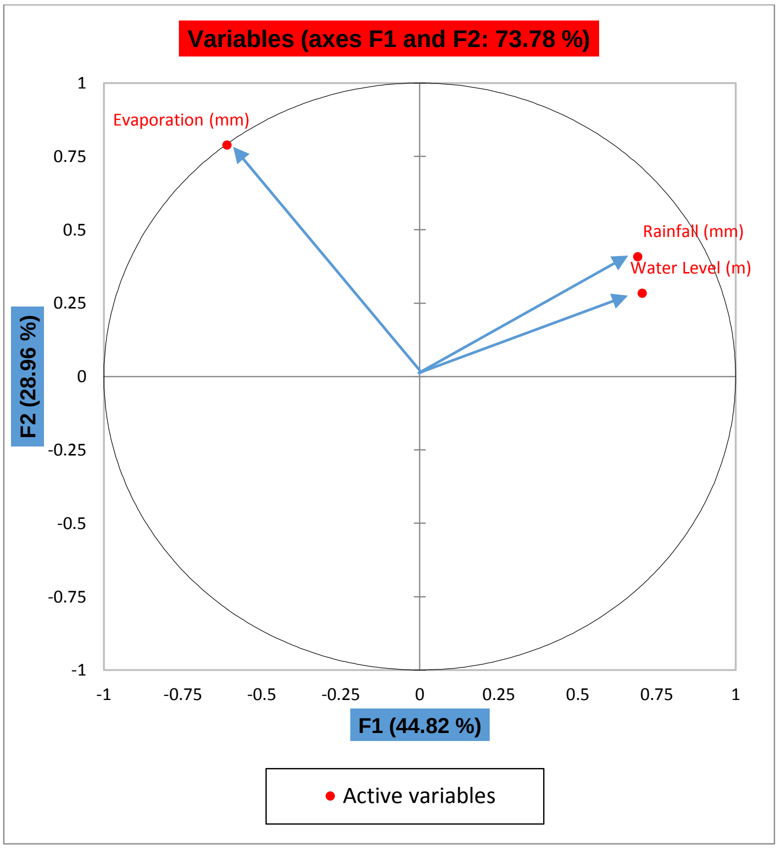


Figure 2: Factor loadings plot after Varimax Rotation

Pattern of the hydrological parameter and the flood risk in Kinabatangan River, Sabah

Meanwhile, Figure 3 showed the illustration of water level with UCL (26.137 m), AVG (13.069 m), and LCL (0.00 m). Throughout the years, the water level was continuously high, as floods were a major problem in Sabah. There were many social and environmental concerns involved in the resulting shift of land use from rural growth to intense urban development. According to D/iya et al. (2014), based on the flood histories in Sabah vicinity from July 1995 until May 2005, a total of 38 flood cases and 5 deaths had been recorded that caused by the monsoon flood. According to the District Officer of Sabah, as many as 40,000 individuals from 70 villages were affected by the flood. This catastrophic flood occurred coincidently with continuous heavy rainfall and affected by the tail of typhoon Phanfone and typhoon Vongfong (D/iya, 2014). Another recent flood disaster in Sabah state occurred in September 2007 and May 2013 which were also affecting several villages, but there was no death occurred (Roslee & Norhisham, 2018). The main causes of flooding could be increased the runoff rates due to the urbanisation, localised continuous heavy rainfall and inadequate river capacity.

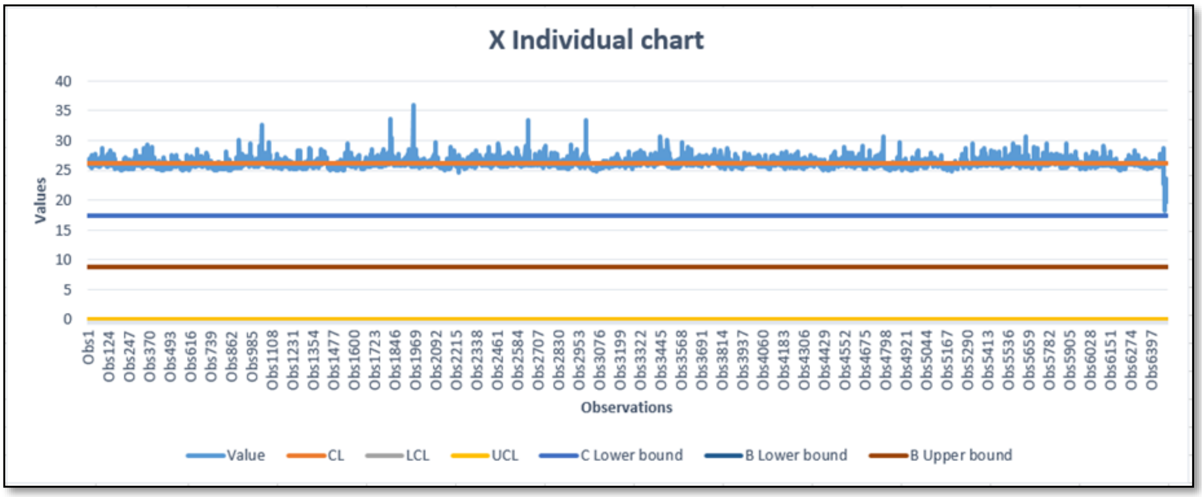


Figure 3: SPC graph based on water level

Nevertheless, in the middle and until recent years, the level of water began to stabilize or moderate due to the mitigation measures taken, especially after the year 2005. The alternatives include channel re-alignment or diversion, and channel concretization. The non-structural flood protection measures involve the installation of flood forecasting and warning systems and development control measures. Flood mitigation work was carried out primarily to reduce or minimize flooding by improving drainage in areas vulnerable to flooding. Since 2006, several river basin studies or drainage master plans had been carried out for rivers where significant flood issues had occurred, including in the Kinabatangan River (Roslee & Norhisham, 2018).

Flood Risk Index (FRI) of Kinabatangan River

The flood risk index range was between 0- 100. The risk setting for 70 and above was classified as High Risk Class, followed by Cautionary Zone Class with a range of 35-69 and 0-34 range classified as Low Risk Class, as illustrated in Figure 4.

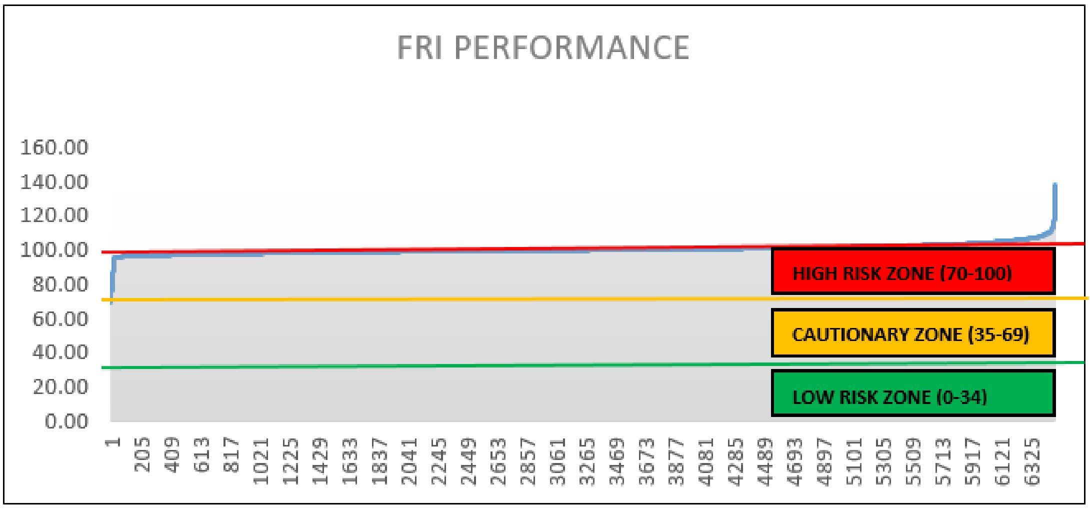


Figure 4: Flood Risk Index (FRI) Performance

Figure 5 explained the level of risk for the water level in the Kinabatangan River, Sabah. The result showed that 99% out of total result being classified as High Risk Class with a range of 70 and above risk index, 1% classified as a Cautionary Zone Class with a risk index from 37.14, meanwhile 0% fall into low risk class with a risk index from 0-34. From the results, the study clearly showed that Kinabatangan River was prone to flood occurrence, as there is 99% out of 100% was included in High-Risk Class.

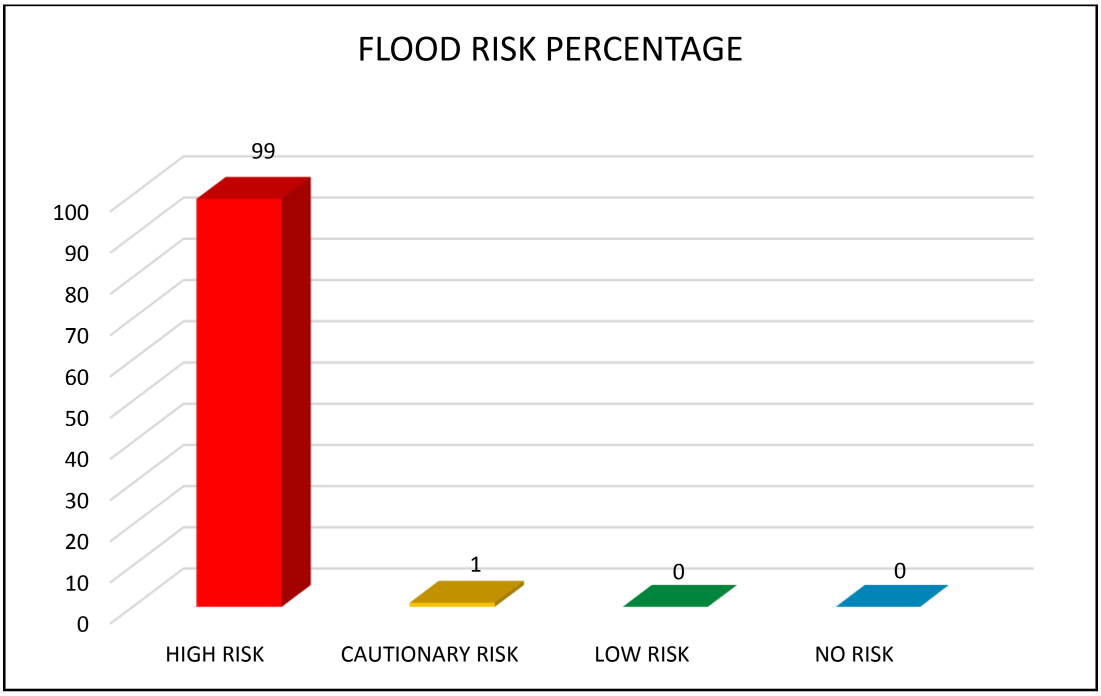


Figure 5: Percentage for Flood Risk Index (FRI)

CONCLUSION

The study evaluated the spatial variation hydrological data in the Kinabatangan River, Sabah by the application of chemometrics technique. Twenty-eight years database (1991-2019) was used in this multivariate statistical analytical study. Using PCA, only water level (44.82 %) were selected for further analysis, whereby it shows the strong factor loadings towards the flood occurrence in the study area. Then, a control chart parameter was derived to identify the occurrence of any alarming values that exceed the normal values and the result showed the illustration of water level with UCL (26.137 m), AVG (13.069 m), and LCL (0.00 m). Following to that, the result from FRI method showed that 99% out of total result being classified as High Risk Class with a range of 70 and above risk index, 1% classified as a Cautionary Zone Class with a risk index from 37.14, meanwhile 0% fall into Low Risk Class with a risk index from 0-34. Therefore, from the results, the study clearly showed Kinabatangan River was prone to flood occurrence, as there is 99% out of 100% was included in High Risk Class. Concisely, the results of this study indicated that the integration of chemometrics techniques provided a powerful tool for decision-making procedures in flood mapping, as it allows a coherent and efficient use of huge analytic data. The development of FRI model would be a very valuable resource for consulting, planning agencies and local governments in managing hazard or risk, estimation of damage, good governance, and remediation efforts to mitigate flood risks. Awareness regarding flood issues was not just the responsibility of the local authorities, but all stakeholders, covering both the public and private sectors.

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