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Research paper

New Approach in Analyzing Risk Level of Flood in Tropical Region: A Case Study at Pahang River Basin, Malaysia

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Abstract

This study focuses on flood risk recognition factor that leads to major contribution of floods in Pahang River basin, identify the correlation between variables and determine factor that influence the flood risk pattern in Pahang. Four hydrological variables been applied. Chemometric technique of Principal Component Analysis (PCA) method and Statistical Process Control (SPC) method were being applied to identify the main contributor for flood, predicting hydrological modeling and risk of flood occurrence at Pahang river basin. Findings from Principal Component Analysis (PCA) confirmed that all selected variables were significant. The relationship between Suspended Solid and Stream Flow with Water Level were very high with correlation of coefficient value more than 0.7. SPC set up a new control limit for all variables. Data beyond the Upper Control Limit (UCL) value is considered as high risk for flood occurrence. Most of the trend pattern showed in year 2007 as high peak. Rapid development growth and anthropogenic activities caused the sediment of Suspended Solid triggered the Water Level and Stream Flow to arise than normal level. Thus, local authority should take earlier precaution for flood prevention and emergency responses plan at the study area for any development of land by takes obligatory action to the developers especially those development that arise along river channel.

Keywords: *Pahang River basin; Chemometric Technique; Flood Risk; Hydrological Modeling.*

1. Introduction

Rivers act as important role in the economic and social life for people. The cradles of river in many civilizations have developed the river banks, estuaries as well the flood plains. Rivers have always been important aspects in human society and daily life. It is at the banks, confluence, estuaries and floodplains of major rivers that many great civilizations emerged [1]. The revolution of rapid urbanization and industrialization those lead to developments to become overstressed river systems. The event of low flows happen when rapid development generate huge amount of waste from mad-made activities including agriculture, industrial, commercial as well as on the transportation wastes [2].

Flood causes an outcome of climatic changes that include on the temperature patterns and precipitation. The basin drainage circumstances the pre-existing on level of water in the river that consists on the soil characteristics of soil, existence of dams also on the urbanization rate. Consequently, every year, flood varied magnitude and scale exist in diverse parts of the world. In Malaysia, river normally been derived through precipitation process which come from surface runoff and ground water recharge that can be seen at the base flow condition or during periods of lack of precipitation happen and also through the natural or man-made reservoirs. Therefore, one of the most common unforeseen events happen in this country is flood and it happen due to monsoon flood and flash flood [1]. Based on the hydrological perspectives, the dissimilarity between these two disasters is based on the time period taken by river flow to exceed than the normal level. Due to that, the flash flood acquire about some hours to get back to the normal water level but for the monsoon flood it last for thirty days [3, 4].

Pahang River basin is one of the major contributors to the flood in this country. Pahang state is place under Eastern Region in Peninsular Malaysia and been divided into North and South of Pahang. The Department of Irrigation and Drainage (DID) Malaysia has carry out the flood mitigation measure as the mechanism tools in controlling flooding based on how to overcome the flood as Pahang River is use for activities such as for the land management which lead to forest conversion where the watersheds through the years and the changes of land use [5, 6, 7].

Flood commonly happen every year at East Peninsular and the critical part happen during monsoon season that fall within November until December and some cases it continue till early of following year. At the low land area, flood likely to happen compared at the high land area. The economic outcomes of flood give severe in low income especially at the area of flood plain. Meanwhile, at Pahang River basin, flood happen because of the velocity

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flow and the river channel that naturally wide and shallow compared to other river.

Chemometric technique analysis is one of the best methods by which the method itself is easy, uncomplicated and able to produce significant results. This technique is capable to classify which variables will become the main contributor for the changing of other variables and it is regarded as helpful in decision making and problem solving in the local environmental issues. The techniques are widely adopted and are being chosen for multi-criteria decision making which are very efficacious in determining the main contributor for the changes of variable from other variables and classifying variables into its own class. This study utilized hydrological data obtained from the Department of Irrigation and Drainage (DID) for thirty years data. The statistical analysis methods such as correlation test are able to identify relationship among variables while in factor analysis, it is apt to identify which variable is the main contributor for the changing of other variables.

Rapid physical development in the study area inflicts the negative impacts towards the rate of the surface runoff flow into the water body system. This will be affected water level at certain location in the river basin and subsequently may lead to flood. The aim of this study is to clarify surface run off to the river as the main reason for flood occurrence at the study area during monsoon season and focus on the appropriate flood of Pahang River on the factors of variables that lead to the flood risk pattern. The finding in this study would assist in determining the limitation of flood risk based on hydrological data and identify suitable mitigation measures for flood prevention based on prediction at the study area.

2. Materials and Methods

2.1. Study Area

Pahang River basin is located at the eastern part of Peninsular Malaysia which localizes under latitude 2° 48' 45" N and 3° 40' 24" N and between longitudes 101° 16' 31" E and 103° 29' 34" E. Study area of this research is focus at Maran, Pahang as marked in yellow circle in Figure 1. The catchment area maximum length and breadth of Pahang River basin are about 205 km and 236 km respectively and river length is about 440 km long and drains an area of 29,300 km^2 of which 27,000 km^2 lies within Pahang that is about 75 percent of the State and about 2,300 km^2 is located in Negeri Sembilan.

Pahang River is divided by Jelai River and Tembeling River start flow in south east and south directions and from north passing along through major town such as Kuala Lipis, Jerantut and Temerloh. The final turning eastward happens at Mengkarak in central south near the coast before it discharging into the South China Sea. The annual rainfall basin is large proportion with 2,170 mm perspective that happen during North East Monsoon between middle of October and middle of January.

Fig. 1: Location of monitoring stations at Pahang River basin

Table 1: Location Station Monitoring at Pahang River Basin

Station Number	Latitude	Longitude	Locations	Variables
Site 3425088	3° 29' 00" N	102°35' 10" E	Kg. Chenor S.M.R.K	Rainfall
Site 3527410	3° 30' 45" N	102° 45' 30" E	Sg. Pahang, Lubuk Paku	Stream Flow
Site 3527510	3° 30' 45" N	102° 45' 30" E	Sg. Pahang, Lubuk Paku	Suspended Solid
Site 3527410	3° 30' 45" N	102° 45' 30" E	Sg. Pahang, Lubuk Paku	Water Level

2.2. Statistical Analysis/ Pre-Processed Data

2.2.1. Chemometric Technique

Chemometric technique such as application of Factor Analysis is able to see the reduction of variables into a set of factors for further analysis. Researcher rarely collect and analyze data with an idea about how the variables are related and application of these method able to make comparison which variables that effecting the most towards the change of the hydrological modeling at the study area with a cheap cost and quicker compare to other technique. The reduction of variables into a set of factors for further analysis can be observed using Chemometric technique, such as the utilization of Factor Analysis. With this technique, variables with the biggest influence in the change of the hydrological modeling at the study area can be compared in a cost effective and quicker manner compared to other techniques.

2.2.2. Principle Component Analysis (PCA)

The application of PCA in this study is to determine the large number of variables into smaller sets. Factor analysis variables and latent construct are measured will establish between the two elements and validity evidence of self-reporting scales. This method reduces the number of variables, examines on the structure or relationship between variables in the hydrological data and detects any the non-dimensionality of theoretical construct. It also includes the multi co-linearity which involves two or more variables that re-correlated, which was carried out in this study. On the other hand, the PCA will look into the relationship between the variables and identify the strongest relationship. Based on the results, it able to point out which variables involve in development that causes the biggest impacts on hydrological modeling at the Pahang River basin.

The PCA was carried out by using XLSTAT 2017 software and the results are used for discussion. Equation used refers in (1):

$$Zij = ai^1 xj^1 + ai^2 xj^2 + ai^3 xj^3 + aimx \quad (1)$$

Z = Component score,
a = Component loading,
x = Measured of variables,
I = Component number,
m = Total variables

2.2.3. Statistical Process Control (SPC)

Time Series Analysis is very important in prediction of water level at the study area. By using this method, it will evaluate on the process from the performance of the analyzed data efficiently. It produced three important results, which important in predicting the hydrological modeling in the future, and those result were Upper Control Limit (UCL), Control Limit (CL) and Lower Control Limit (LCL) in the control chart is represented within the range value of a set of data. The Control Chart has the ability to uncover some trends and patterns, showing actual data deviations from the historical baseline and dynamic threshold, being able to capture unusual resource usage and becoming the best base lining to show how actual data are deviated from historical baseline. The equation used refer in (2)-(3):

Moving Range = Plot: MRt for t = 2, 3, ..., m. (2)

MR = average moving range
t = time
m = individual values

Average Value: $\bar{x} = \frac{\sum_{i=1}^{m} x_i}{}$ (3)

$\bar{X}$= moving range
m= individual values
x_i= individual values

3. Results and Discussion

3.1. The Relationship between Variables that Contribute to Flood Occurrence

To identify whether monsoon season or human development has become the major reason for flood occurrence, Spearman's correlation coefficient analysis was applied and the result summarized in Table 2.
Based on Figure 2 and Table 2, the Spearman Correlation Test showed high correlation between the Stream Flow, Suspended Solid and Water level, with p-value less than 0.0001. Based from the results shown in Table 2, Rainfall was not a major cause for the increase of Water Level at the study area. It was clear that Suspended Solid showed a very strong correlation for the changing rate of Water Level where Suspended Solid described the rate of surface run-off that flowed into the water body. This explains that the risk of flood is unrelated to the monsoon season. The result from the Spearman Correlation Test clearly showed that the surface run-off had become the major impact for the increase of water level in the study area.

Table 2: Correlation Matrix (Spearman Correlation Test)

Variables	F1	F2	F3	F4
Stream Flow	0.992	-0.045	-0.091	-0.068
Suspended Solid	0.987	-0.041	0.155	-0.009
Water Level	0.994	-0.044	-0.063	0.077
Rainfall	0.130	0.991	-0.001	0.000

3.2. Factor that Contribute to Flood Occurrence

From the result, it showed that Rainfall was less significant compared to the Stream flow, Suspended Solid and Water Level when the p-value for these elements were less than 0.001. This clearly explains that the monsoon season does not pose risk of flood in the study area and the change of hydrological modeling is significant to be compared with the surface run-off at the study area rather than North East monsoon.
Fig. 2 and Table 3 show the variables with significant impact towards the hydrological modeling at the study area. From Table 3, the Stream flow, Suspended Solid and Water Level resulted in the highest coefficient; 0.992, 0.987 and 0.994, respectively. If the coefficient is more than 0.7, it is considered as strong coefficient. Hence, it is the human development that caused high rate in the surface run-off that affected the Water Level and the Stream Flow. This analysis also reduced the variables by looking into the most significant variables for further analysis. There is high flood risk if no limitation is set for mitigating action.

Table 3: Correlation between Variables and Factors

Variables	Rainfall (mm)	Stream Flow (m^3/s)	Suspended Solid (tonnes/day)	Water Level (m)
Rainfall	1	0.084	0.088	0.086
Stream Flow	0.084	1	0.968	0.989
Suspended Solid	0.088	0.968	1	0.973
Water Level	0.086	0.989	0.973	1

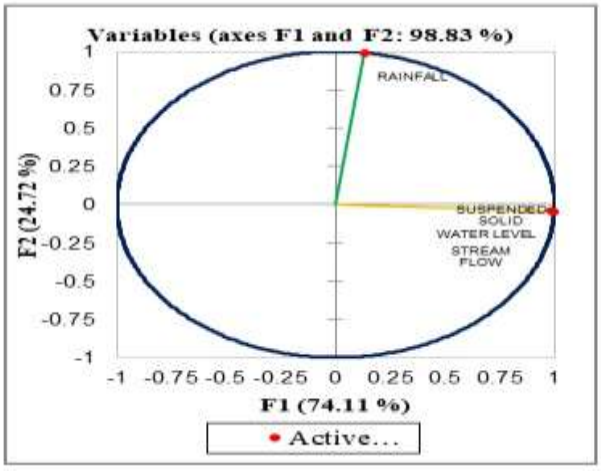

Fig. 2: Correlation between Variables and Factors

3.3. Flood Control Warning System

Statistical Process Control was applied as the time series analysis been carried out for further analysis in this study by referring to Control Chart Builder. This method was being applied to determine the limitation for all variables which have become factors for flood occurrence at Pahang River basin. Based on this method, the output from the analysis will be able to be used as control limit for flood control. There will be three phases for control limit and those phases are Upper Control Limit (UCL), Average Limit (AVG) and Lower Control Limit (LCL).
Based on Figure 3, it illustrates the rate of Suspended Solid at Pahang River basin. Result show that the rate of Upper Control Limit (UCL) value in the study area was 13.357 sediment tonnes/day. While the Average Limit (AVG) shows value of 9.322 sediment tonnes/day and 5.288 sediment tonnes/day for Lower Control Limit (LCL) value. The limit control for Suspended Solid explain on limitation for Suspended Solid discharge at Pahang River basin. The rate which is beyond control limit for Suspended Solid will be effecting the changes of Water Level for flood occurrence and could trigger the flood occurrence at the study area.
This explain, the increment of sedimentation loads in river caused higher surface runoff and caused sediments generated from uncovered land be conveyed by surface runoff into drainage system nearby and diminished drainage capacity of the river [8]. Utilization of natural resources such as land use, erosion, and intensive development may disturb flood event and stream degradation [9].

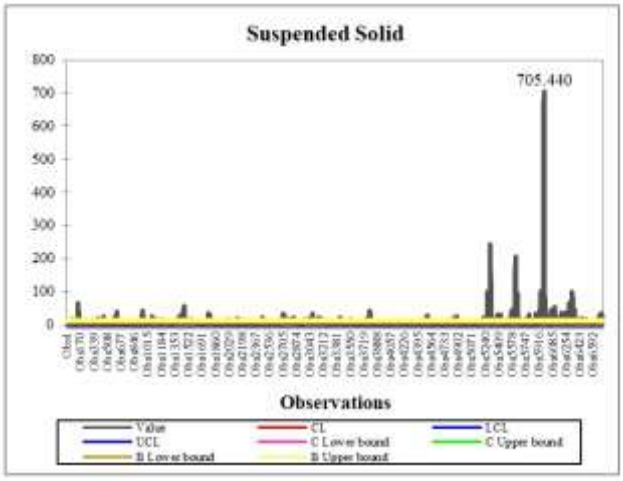

Fig. 3: SPC Result for Suspended Solid at Pahang River basin

Stream Flow becomes one of the variables that emerged among the main factors for flood occurrence at the study area. Result in Figure 4 explains that the Upper Control Limit (UCL) for Stream Flow at Pahang River basin is 888.797m^3/s, 692.207m^3/s for Average Limit (AVG) and 495.618m^3/s for Lower Control Limit (LCL) value. Stream Flow is one of the variables which turned out to be the factor for flood occurrence and all data which are located above Upper Control Limit is high risk for flood occurrence.

Loaded of sedimentation in river caused higher surface runoff and the process of transport and erosion happen caused sedimentation to deposit along river. The speeds of stream flow determine the central capacity of the sedimentation of river basin in order to move and transport. The slower the speed means the area study been affected by increment of large sedimentation. Thus, the process of deposit of sediment depends on the river discharge and the speed of the river [10].

The higher peak in the trend graphs of Stream Flow are matched with major flood history that happen in Pahang state, which obviously affected by the increase in precipitation that can be visualized by referring the stream flow and water level [11].

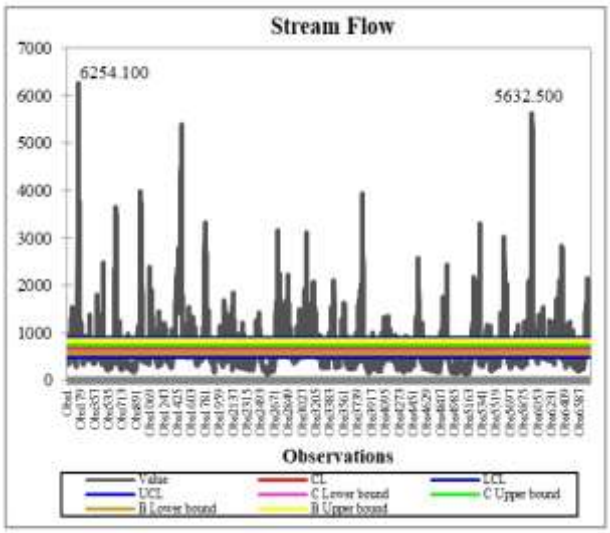

Fig. 4: SPC Result for Stream Flow at Pahang River Basin

Based on Figure 5, it explains that the Upper Control Limit (UCL) for Water Level at Pahang River basin comprises of 14.175m and 13.624m for Average Limit (AVG) and 13.074m for Lower Control Limit (LCL). From this result, for the rate of Water Level above Upper Control Limit is considered as high risk to face flood occurrence and the most stable condition is the rate for Water Level within Average Limit and for Water Level below Lower Control Limit is being regarded to be no possibility for flood occurrence.

Rapid development inflicts the negative impacts towards the rate of the surface runoff flow into the water body system which can be affected the water level at certain location in the river basin and subsequently may lead to flood [12]. River flow might be change due to drastic form from human activities taking along river basin. Thus, it gives changes in hydrodynamic of Pahang River basin.

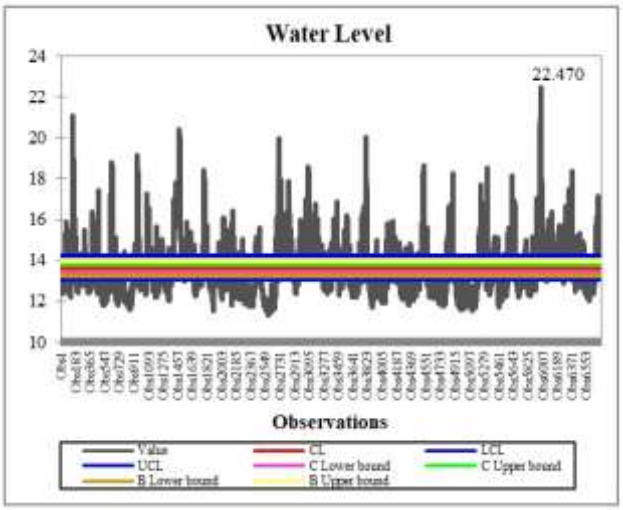

Fig. 5: SPC Result for Water Level at Pahang River Basin

Based on Figure 6, it explains that the Upper Control Limit (UCL) for Rainfall at Pahang River basin comprises of 26.839mm and 5.342mm for Average Limit (AVG) and -16.16mm for Lower Control Limit (LCL). Trend pattern analysis of Rainfall in the Pahang River basin was highly variable in spatial and temporal dimensions based on monthly, yearly, and monsoon temporal scales. Pahang River basin usually been affected by the North East monsoon that happened normally in November to March by heavy rainfall that significantly result in flood especially at the east cost of Peninsular Malaysia [13]. Although flood in Pahang River basin been affected by heavy rainfall but severity of main driver of human man-made activities need attention especially flood happen when river basin and it surrounding environment condition trigger to flood event.

Hydrological cycle been disturbed at the study area causes the surface run off becomes higher and caused the precipitated on the surface ground of river. The circumstances caused rate of rainfall was low due to the flood occurrence take place easily [14]. Developments and human activities around study area act as contributor that affects the climate change which not based on monsoon phase anymore.

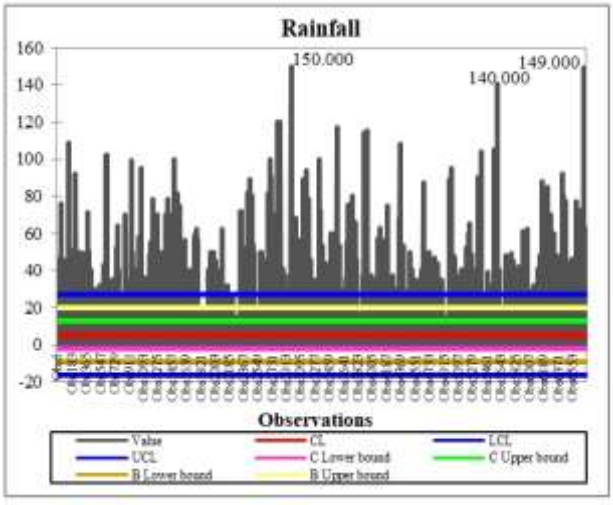

Fig. 6: SPC Result for Rainfall at Pahang River Basin

4. Conclusion

In conclusion, based on the analysis which has been carried out in this study, clearly monsoon season rainfall is not become the major factor for flood occurrence and its correlation with changes of water level also not strong at the study area. Chemometric Technique help to identify which variables show high correlation coefficient among the variables and the time series analysis was able to identify the limitation for all factors that affect the most for the changing of the water level based on the results from the correlation test and factor analysis.

Effectiveness of the mitigating measures depends on the awareness and strong legal enforcement in controlling the rate of the surface run-off which comes from uncontrolled human development. Local authority should take earlier action for flood prevention and emergency response plan for citizen of Pahang when the limitation for major contributor for flood occurrence has been set. Local government also able to enforce stricter action towards developer especially for development along the river in order to control the excessive amount of surface run-off into the river by following guideline based on Environmental Quality Act 1974.

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