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EXPLORE POSSIBLE CLIMATE CHANGE IMPACTS ON SURFACE FLOODING IN KELANTAN

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ABSTRACT

Floods are a common occurrence in Kelantan, one of the states in Malaysia that located on the east coast of Peninsular Malaysia. However, in recent times, due to the large scale of climate change, geographical characteristics and unplanned urbanisation, Kelantan has become extremely vulnerable to flood year by year. This study is focused on exploring the relationship between climate change and flooding in Kelantan River, Lebir River and Galas River. Besides, it also to determine which

period of months has the highest frequency of peak rainfall volume, water level and stream flow. Furthermore, a high accuracy and performance forecasting tool that can be used to forecast the future hydrological data also need to be determined. This research is very crucial that it can allow the respective department to carry out comprehensive planning and early preparation before flooding occurs. A series of data of the study area were collected and analysed. It is observed that the rainfall volume, water level and stream flow are interrelated. When rainfall volume increases, the water level and stream flow will also increase and vice versa. Next, it is found out that November to January has the highest frequency of peak hydrological data due to the North East Monsoon season. Artificial Neural Network or also known as ANN was used to predict the future hydrological data and the results were compared with the actual data. It is observed that the ANN can perform very well in forecasting the future hydrological data with high accuracy and performance.

Key words: Floods, Kelantan and climate change.

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1. INTRODUCTION

With the changing of the climate around the world, we have seen a lot of changes along with the changing pattern of weather and hydrology. Global warming over the last century leads to heat extremes that previously occurred once every 1000 days. However, the frequency has been increased four to five times more often in present day. [1] The probable effects of climate change have led to weather extremes.

Previous studies have indicated that the predominant factor which impacts the hydrological cycle and flooding is climatic variability or climate change effects. Climate change effects, such as increasing of temperature, evaporation and precipitation will cause flooding to occur. Flooding is one the most severe natural hazards, however, climatic and land use changes have been the main factor of increases in flood frequency and magnitude. Climate change will lead to a higher intensity and a prolonged rainfall which will directly impacts on the frequency, magnitude and duration of flood especially at those monsoon catchment areas. [2]

Floods are a common occurrence in Malaysia with specific attention was given to monsoon flooding and flash floods. From historical overview, the first reported severe and devastating flood event dates as far back as 1886 that happened at Kelantan which had caused extensive damages. Next was the floods in 1927 and 1967, where catastrophic floods sweep again in Kelantan. [3] Most importantly, Kelantan experienced the most significant and largest recorded flood in the history of Kelantan in 2014. The degree of the floods was considered as ‘’tsunami-like disaster’’ in which around 200,000 victims were displaced. This flood was called ‘Big Yellow Flood’’ because of its high intensity of mud. [4] According to the Malaysia Meteorological Department (MMD), the amount of rainfall received at Kelantan River Basin throughout the three days event at 2014 was more than 600 mm. [2] Despite large costs have been used to manage and control flooding in Malaysia, but still does not solve flood event completely. Furthermore, flooding occurs at urban areas is expected to increase in the future in terms of frequency and duration of floods. [5] Therefore, Kelantan River Basin is

an important study area because it is subject to the most devastating flooding in Malaysia and it will flood frequently when heavy rain occurs.

According to the Köppen climate classification system, Malaysia is a fully humid and its location is near to the equator. It is a country that is highly vulnerable to climate change impacts and deserve more attention especially Kelantan, yet there were lack of research and information about the relationship between climate change factor and flooding in Kelantan River. Even though flooding is unavoidable, the respective authorities and the general public should know when and where the next flood is going to occur. Therefore, past years of hydrological data of the area need to be analysed and an accurate forecasting tool is needed to predict the future hydrological data in order to have early preparation before future disasters occurs at Kelantan River.

2. RESEARCH METHOD

Hydrological data such as rainfall volume, water level and stream flow for Lebir River, Galas River and Kelantan River were collected from the Department of Irrigation and Drainage Malaysia (DID). The two principal tributaries of Kelantan River which is the Galas River and Lebir River merge immediately upstream of Kuala Krai after which the Kelantan River meanders over a wide and flat coastal plain before discharging into the South China Sea. In other words, Kelantan River is located at the downstream while the upstream is Galas River and Lebir River. Therefore, Kelantan River is the mouth and the final discharging point of water to the South China Sea. 9 years of hydrological data which is from year 2009 to year 2017 will be used in this research to ensure higher accuracy and performance. The data are in terms of hourly and daily interval to provide a detailed and clear representation of rainfall, water level and stream flow characteristics of the study area.

The effectual relationship between the hydrological data of Lebir River and Galas River for the past 9 years will be built up by using Microsoft Excel to analyse the impacts of climate change on water level and stream flow of the study area. The rainfall volume, water level and stream flow data will be analysed and compared to determine whether they are interrelated. It is used to determine whether climate change impacts on rainfalls will greatly affecting the water level and stream flow or vice versa. Besides, the analysed past data will also show which period of months has the highest frequency of peak hydrological data and check whether it is due to the Monsoon period of Malaysia.

Artificial Neural Network or also known as ANN is a useful tool for classification, forecasting and modeling the climate change and ecological research. ANN by STATISTICA will be used in this research to predict the stream flow of Kelantan River (downstream) by using the hydrological data of Lebir River and Galas River (upstream) as input. After that, the predicted data will be compared to the actual data to determine its accuracy, performance and error.

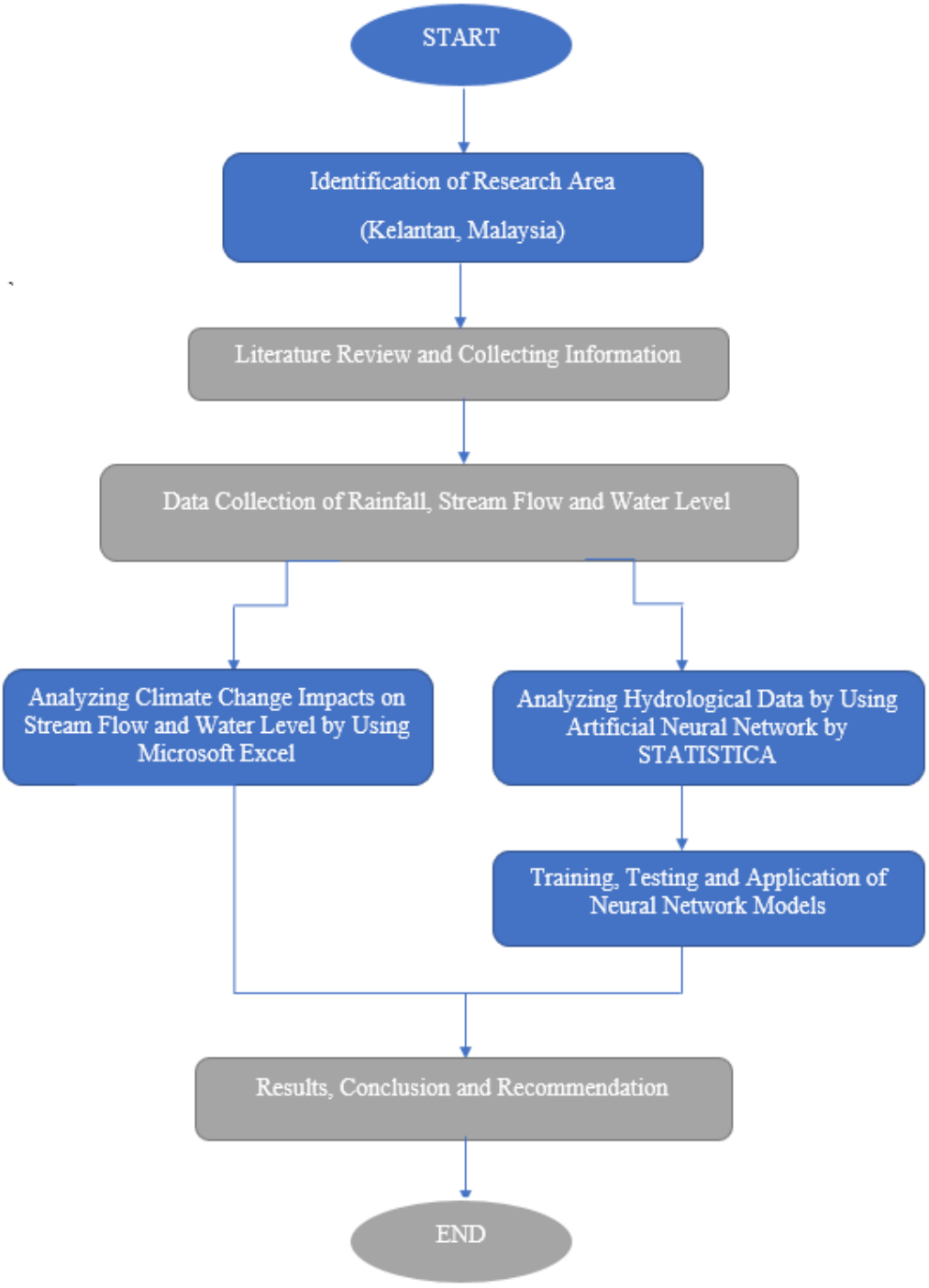

Figure 1 Methodology flow chart

3. RESULTS AND ANALYSIS

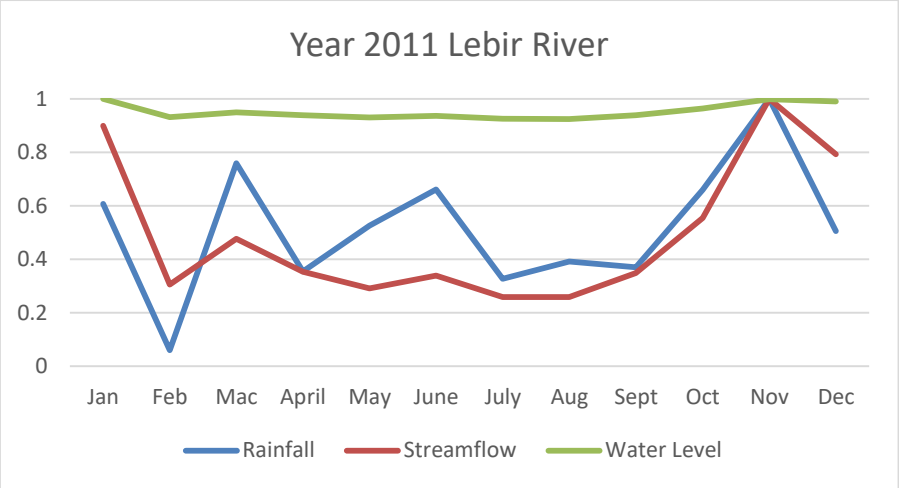

Figure 2 Year 2011 Lebir River mean monthly rainfall, stream flow and water level

Figure 2 above showed the line chart of one of the years for Lebir River which is year 2011, it can be seen that the peak rainfall volume and stream flow were in November while the peak water level was in January. Besides, when the rainfall volume decreases in a particular month, the stream flow and water level will also decrease in that month and vice versa.

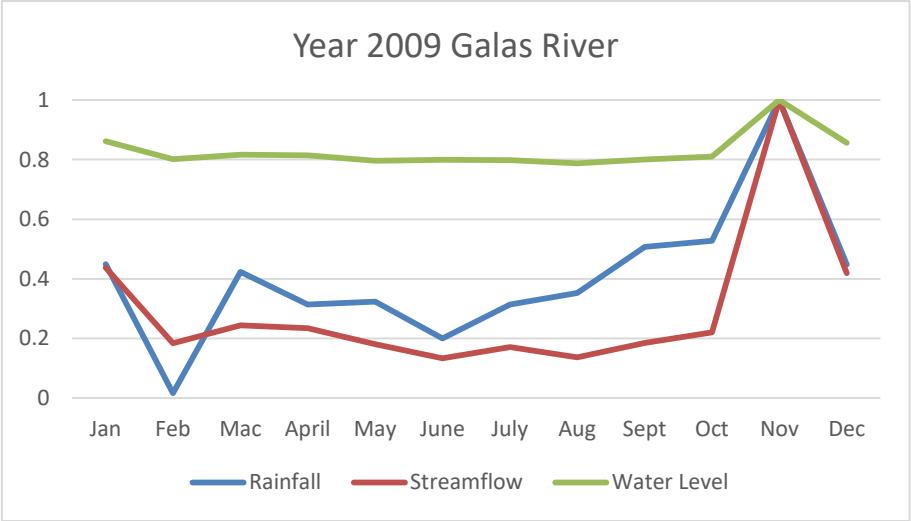

Figure 3 Year 2009 Galas River mean monthly rainfall, stream flow and water level

Figure 3 above showed the line chart of one of the years for Galas River which is year 2009, it can be seen that the peak rainfall volume, stream flow and water level were in November. Besides, when the rainfall volume increases in a particular month, the stream flow and water level will also increase in that month and vice versa.

Table 1 Summary of peak hydrological data for Lebir River from year 2009-2017

Year	Month											
	Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
2009	SF,WL										RF	
2010												RF,SF, WL
2011	WL										RF,SW	
2012	SF,WL											RF
2013												RF,SF, WL
2014												RF,SF, WL
2015											RF	SF,WL
2016						RF						SF,WL
2017	RF,SF, WL											

Parameters Description

RF = Rainfall

SF = Stream flow

WL= Water level

Table 1 above showed the summary of peak hydrological data for Lebir River from year 2009 to year 2017. It can be concluded that most of the peak rainfall volume, stream flow and water level were during November to January except the rainfall volume in year 2016 which was in June.

Table 2 Five models developed by Artificial Neural Network

Index	Net. Name	Training Performance	Test Performance	Training Error	Test Error
1	MLP 4-9-1	0.663420	0.657311	0.000764	0.000738
2	MLP 4-10-1	0.895904	0.885871	0.000268	0.000283
3	MLP 4-6-1	0.815095	0.794534	0.000453	0.000473
4	MLP 4-10-1	0.904570	0.903732	0.000245	0.000239
5	MLP 4-5-1	0.708387	0.666382	0.000730	0.000779

Table 2 above showed the five models developed by Artificial Neural Network when forecasting the future hydrological data. It can be seen that the forth model which is MLP 4-10-1 has the highest training and test performance which is 0.904570 and 0.903732 respectively. Besides, it also has the lowest training and test error which is 0.000245 and 0.000239 respectively. Thus, it has been chosen as the best model in this research.

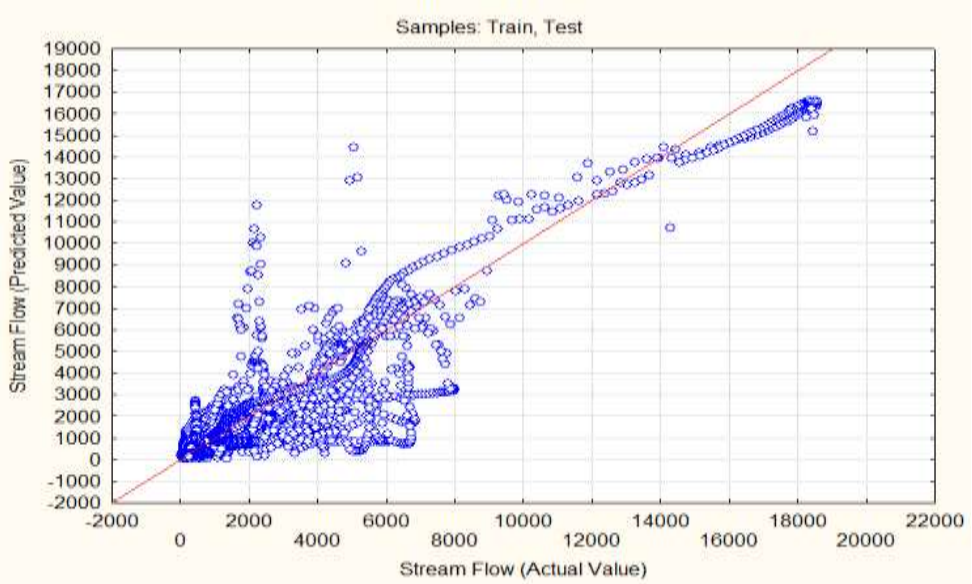

Figure 4 Actual stream flow value (target) vs. projected stream flow value (output) for forth model

Based on Figure 4 above, most of the results which is the actual stream flow value (Target) and projected stream flow value (Output) are very close to the center line of the graph.

This showed that the accuracy and performance of the forth model is very high and it also has very low training error and test error.

3.1. Line Chart of Lebir River and Galas River

Overall, when analysing the line chart of mean monthly rainfall volume, stream flow and water level in year 2009 to year 2017 for Lebir River and Galas River, it can be seen that the hydrological data such as rainfall volume, stream flow and water level are interrelated. It demonstrates that the stream flow and water level have a positive relationship with the rainfall. When rainfall volume decreases in a particular month, the stream flow and water level will also decrease in that month and vice versa. In other words, when large amount of rainfall occur will induce huge amount of excess water or also known as runoff that will flows to the river. As a result, the stream flow or the peak discharge of the river will increase. Furthermore, excess runoff that flows to the river will also increase the water level. In short, when the rainfall volume and frequency increases, the streamflow and water level will also increase and vice versa.

3.2. Summary of Peak Hydrological Data for Lebir River and Galas River

Overall, when analysing the tables of summary of peak hydrological data for Lebir River and Galas River from year 2009 to year 2017, most of the peak value of hydrological data such as rainfall volume, streamflow and water level were during November to January. This is due to the North East Monsoon in Malaysia which occurs during October to March. The large amount of rainfall is originated from the North Pacific and China and is brought to the North East area of Malaysia such as Kelantan, Terengganu and Pahang. Therefore, when huge amount of rainfall occurs, the stream flow and water level will increase. As a result, November to January have the highest frequency of peak hydrological data which is rainfall volume, stream flow and water level and is subjected to high risk of flooding.

3.3. Forecasting Future Hydrological Data by Using Artificial Neural Network

After entering all the input and target value, Artificial Neural Network started to analyse the data and it came out with five different models as shown in Table 2. The five different models have different training algorithm, training performance, test performance, training error, test error, hidden activation and output activation. ANN will adjust the connection weight repeatedly until it successfully produces output value that match the initial data. All of the models above have different number of repeating process which will affect their training and test performance. The forth model which is MLP 4-10-1 has underwent 10 times of repeating process and has the most repeating process among the five models. As a result, it has the highest training and test performance and lowest training and test error between actual value and projected value. In other words, it has the highest accuracy when projecting future hydrological data.

4. CONCLUSION

In conclusion, impacts of climate change is greatly influencing the water level and stream flow. In other words, climate change is positively related to the streamflow and water level. If rainfall volume increases, the streamflow and water level will also increase and vice-versa. In addition, November to January has the highest percentage increase in rainfall volume, streamflow and water level as compared with other months. This is due to the North East Monsoon season that occurs during October to March and large amount of rain has been brought to Kelantan. In general, if rainfall volume and frequency increases, it will cause the streamflow and water level to increase, as well as potentially occur of flooding. Besides, Artificial Neural Networks is a useful and realiable tool for classification, forecasting and modeling the changes of climate and ecological research. ANN perform better when compared to traditional statistical methods. This is due to ANN can execute complex issues and insimulating nonlinear system behaviors with higher accuracy and speed. However, the application of ANN is not entirely perfect and will not replace traditional methods completely as it still contains some flaws. For example, it cannot explain its “black box” behavior, overlong traning and testing times and data over-fitting. However, by integrating and combining these traditional methods, modern methods and technologies into a decision-support system, surely ANN will be a common and useful tool in studies and research of climate change impact and ecology in the future

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