***IMPACT OF LAND USE CHANGES TO HYDROLOGICAL REGIME IN NERUS CATCHMENT, TERENGGANU, MALAYSIA***

**MOHD HAFIFI BIN MAT NAZIR**

**FPAS 2016 3**

# IMPACT OF LAND USE CHANGES TO HYDROLOGICAL REGIME IN NERUS CATCHMENT, TERENGGANU, MALAYSIA

**By**

**MOHD HAFIFI BIN MAT NAZIR**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science**

**May 2016**

All Praise To Allah;

Whom I bear witness of His Oneness; and to whom I owe everything

To my parents, Mat Nazir Bin Yaacob and Che Sepiah Binti Awang. The most patient, the most loving.

This one is for you

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the Degree of Master of Science

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**May 2016**

**Chairman : Professor Wan Nor Azmin Bin Sulaiman, PhD**
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Hydrological response in a water catchment area is dominantly received the greatest changes as the impact of changes in land use and magnified by climate influence. The hydrological response can be simplified through expression of Runoff Coefficient (RC) that has been in years of application in the field of hydrology and hydraulic studies.

Several current methods applied in this study were covering of rainfall-runoff polygon method and cluster analysis. Both of these methods used for identifying the impact of land use and climate variability on the monthly RC. These methods were able to analyse both the main factor in various verse of interpolations. For modelling purposes, hybrid neural network model was adapted successfully to predict the RC. It was a combination between the time series of RC and neural network.

The findings summarize that new method of rainfall-runoff polygon method capable of becoming one of the useful methods with innumerable output exploration which covered a variety of interpretations in the catchment hydrology studies. In addition, the analysis of clusters is suitable to be used as a method of practice in analysing the impact of land use and climate on the hydrological response in a catchment area. Modelling techniques with application of hybrid neural network used in this study able to produce an accurate RC prediction even with the use of restricted hydrological data.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

**IMPAK PERUBAHAN GUNA TANAH KE ATAS CIRI-CIRI HIDROLOGI DI TADAHAN NERUS, TERENGGANU, MALAYSIA**

Oleh

**MOHD HAFIFI BIN MAT NAZIR**

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Tindakbalas hidrologi dalam suatu kawasan tadahan air merupakan impak daripada perubahan guna tanah dan magnifikasi faktor cuaca. Tindakbalas hidrologi boleh dimudahkan melalui ekspresi Pekali Aliran (RC) yang telah lama diaplikasikan dalam bidang hidrologi dan hidraulik.

Beberapa kaedah terkini telah digunapakai dalam kajian ini yang merangkumi kaedah poligon hujan-aliran dan analisis kluster. Kedua-dua kaedah ini digunakan bagi mengenalpasti impak perubahan guna tanah dan cuaca terhadap RC bulanan. Kaedah-kaedah ini berupaya untuk menganalisis kedua-dua faktor utama ini dalam pelbagai versi yang berbeza. Bagi tujuan pemodelan RC, teknik hibrid rangkaian neural diadaptasi dengan jayanya. Ianya merupakan kombinasi antara siri masa RC dan rangkaian neural (NN).

Hasil kajian ini merumuskan bahawa kaedah yang baru iaitu Kaedah Poligon Hujan-Aliran berupaya menjadi salah satu kaedah terkini yang ringkas dengan analisis output yang pelbagai merangkumi pelbagai interpretasi kuantitatif dan kualitatif dalam aspek keseluruhan kitaran hidrologi. Selain itu, analisis kluster juga sangat sesuai untuk dijadikan satu kaedah amalan dalam menganalisis impak guna tanah dan cuaca terhadap tindakbalas hidrologi dalam suatu kawasan tadahan. Teknik pemodelan dengan aplikasi hibrid rangkaian neural dalam kajian ini mampu menghasilkan ramalan RC yang tepat walaupun dengan penggunaan data hidrologi yang terhad.

**ACKNOWLEDGEMENTS**

All praises to Allah, the Almighty and the Most Merciful. It is with His sustenance that the study has come to fruition. My humblest gratitude goes to my committee Chairman, Prof Dr Wan Nor Azmin Sulaiman for his constant guidance, thoughtful insights and unending motivationsthat he provided me with at every stage of the study. I am also enormously grateful to Assoc Prof Dr Hafizan Juahir, member of the supervisory committee whose suggestions have helped a lot in improving the final product of the research.

I certify that a Thesis Examination Committee has met on 17 May 2016 to conduct the final examination of Mohd Hafifi bin Mat Nazir on his thesis entitled "Impact of Land Use Changes to Hydrological Regime in Nerus Catchment, Terengganu, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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**Declaration by graduate student**

I hereby confirm that:

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This is to confirm that:

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| | |
|---|---|
| DDM | Data Driven Modelling |
| ANN | Artificial Neural Network |
| FIS | Fuzzy Inference System |
| SVM | Support Vector Machine |
| GP | Genetic Programming |
| AR | Autoregressive |
| MA | Moving Average |
| ARIMA | Autoregressive Integrated Moving Average |
| ARIMAX | Multivariate Autoregressive Integrated Moving Average |
| MLR | Multiple Linear Regression |
| ACF | Autocorrelation Function |
| PACF | Partial Autocorrelation Function |
| AA | Autocorrelation Analysis |
| LCA | Linear correlation Analysis |
| IVS | Input Variable Selection Method |
| SARIMA-NN | Seasonal Autoregressive Integrated Neural Network |
| SD-NN | Seasonal Decomposition Neural Network |
| MLR-NN | Multiple Linear Regression Neural Network |
| WHAT | Web based Hydrograph Analysis Tool |
| GIS | Geographic Information System |
| PS | Polygonal Sides |
| PSQ | Polygonal Sequence |
| SSP | Size and Shape of Polygon |
| LPP | Length of Polygon Peripheral |
| SPS | Slope of each Polygon Sides |
| $R^2$ | Coefficient of determination |
| $E^2$ | Coefficient of efficiency |
| AVR | Average relative variance |
| RC | Runoff Coefficient |
| MLR | Multiple Linear Regression |
| HNN | Hybrid Neural Network |

| | |
|---|---|
| NEM | North East Monsoon |
| SARIMA | Seasonal Autoregressive Integrated Moving Average |
| SAF | Seasonal Adjustment Factor |
| ERR | Residuals/Error |
| SAS | Seasonally Adjusted Series |
| STC | Smoothed Trend Cycle Component |
| ANOVA | Analysis of Variance |
| SR | Surface Runoff |
| R | Rainfall |
| BF | Baseflow |
| RMSE | Root Mean Square Error |
| SEP | Percent Standard Error of Prediction |
| MAE | Mean Absolute Error |

# CHAPTER 1

# INTRODUCTION

## 1.1 Introduction

The natural hydrologic system consists of a complicated and complex system that involved many processes in its cycle. Events beginning with rainfall and ending with record of stream discharge at observatory station make it very hard to consider the events of infiltration, surface runoff and its movement separately. Veritably, hydrological responses and its characteristics should be observe and analyze for well design studies on water resources development (Yenigun et al, 2008).

Hydrological response usually denoted as Runoff Coefficient (RC) among the hydrologists is complex in nature because of relationships with various factors, e.g., land use, watershed geomorphology, initial moisture, evaporation, infiltration, distribution and duration of the rainfall. Dynamic changes of these factors altering the natural properties of hydrologic variables and thus makes the hydrologists confronted with the problems of prediction and estimation.

Analysis of hydrological response characteristics has been conducted in various ways. It was started from the fundamental evaluation of simple properties of each parameter to a more complicated and computerized model which required various types of related physically distributed dataset. Undeniably, understanding the whole aspects of this hydrological response modelling in a watershed is not a simple task. Thus, an established hydrological response model which is acceptable and provided a dynamic response of hydrologic cycle arises due to the enhancement in the technological aspects. Over the years, several hydrological models ranging from empirical relationships with physically based models have been developed for runoff prediction (Sarita et al, 2014). However, the lacking of scientific data needed in the prediction using physically based model has always become an unacceptable problem in hydrological assessment.

Recently, the use of Data Driven Modelling (DDM) for hydrological model is becoming increasingly important. DDM was developed based on the analysis of existing data using specific mathematical algorithms in intelligent computing system. This type of model is able to explain the relationship between inputs and outputs in the form of mathematical equations without affecting the physical simulation of the real environment (Solomantine and Price, 2004).

Earlier research has shown that the DDM contributed an important role in the overall development of hydrological models. Among of them were Artificial Neural Network (ANN), Fuzzy Inference System (FIS), Support Vector Machine (SVM), and Genetic Programming (GP). These DDM model were successfully applied in modelling rainfall-runoff relationship (Dawson et al, 1998; Rajurkar et al, 2004), water level forecasting (Kisi, 2010), flood forecasting (Campolo et al, 2003; Chang et al, 2007; Sulaiman et al, 2011), stream flow forecasting (Kisi, 2007) and others.

The idea of integrating several techniques under data-driven approaches is a relatively new concept emerges from the current modeling techniques (Corzo et al, 2009). This opened a new chapter to solve the complex problems of hydrology. Furthermore, most of the hydrological data is inherently linear and non-linear. It is not suitable if only focus one method alone although it can solve the problem of non-linear as well. Therefore, the best alternative way is hybridization of techniques in DDM.

In fact, an extensive DDM for a prediction purposes in tropical watershed as in Malaysia is hardly available. As such, climatic variability and dynamic changes of land uses needed a simplistic model and thus the Hybrid ANN is selected. This research demonstrates the use of Hybrid ANN techniques to model the hydrological response in Nerus catchment, Malaysia.

## 1.2 Problem statement

Nerus catchment is the largest tributaries among the 13 sub-catchments in the Terengganu river basin, which potentially contributes to the higher generations of runoff. In fact, Nerus catchment having a rapid development of land uses over the years due to the increase of population and demand of agricultural products (Institut Perundingan UPM, 1994). However, the conversions of land use, mainly forest to agriculture in Nerus catchment may impose significant changes to the natural water balance in that particular area.

Indeed, several places located at the lower part of the catchment, that approaching to Kuala Nerus such as Kampung Tok Jiring and Kampung Banggul Tok Muda were identified to be potentially facing of flooding. Besides, flooding also potentially occur at the upper part of the catchment with two of the locations were located in the tributaries of the Nerus catchment and identified as Kampung Langkap and Kampung Pengkalan Merbau (Terengganu National Council). Hence this study which analyzing the changes of the natural water cycle will be important for the water resources development purposes.

There is no scientific research study in hydrological response modelling using DDM with hybrid techniques conducted in Nerus catchment. Hence, this study is the first research conducted in Nerus catchment to analyse hydrological response characteristics and develop a valuable hydrological model in that particular area. Moreover, in spite of many ANN model has been developed in hydrology, no much study attempts to predict runoff coefficient using this method (Pektas et al, 2013). A few studies conducted by researchers to predict runoff coefficient directly using ANN (Pektas et al, 2013, Parida et al, 2006 and Loke et al, 1997).

In terms of hydrological modelling, physically based models such as DHSVM, MIKE-SHE, and SWAT are better because they consider the controlling of physical processes, but at the same time, their data requirements are also rigorous and highly cost (Thirumalaiah & Deo, 2000; Daniel et al, 2011; Isik et al, 2013). In fact, Nerus catchment is a big catchment area and not much specific hydrologic data can be obtained directly from that particular area due to geomorphological constraint.

Often, even in intensively monitored watersheds, not all the required data are available (Norbiato et al, 2010). Therefore, there is a need to look for alternative methods for the prediction of runoff coefficient using readily available information. Since the hydrological processes in estimate the runoff coefficient has been non-linear and complex processes, the ANN was used to provide a reasonably accurate model without details consideration of physical component for the process under investigation.

By the time, development of hybrid time series-ANN model is still limited in hydrological modelling area (Jain et al, 2007). Moreover, researchers have employed conventional time series analysis with based on Box-Jenkins method such as Autoregressive (AR), Moving Average (MA), and Autoregressive Integrated Moving Average (ARIMA) for such a long time.

Moreover, many critics have been put on the accuracies of the model, which always suffer from the stationarity and linearity (Jain et al, 2007). Thus, to overcome this problem, integration of classical linear model such as Univariate ARIMA and Seasonal Decomposition and other linear regression models such as Multiple Linear Regression (MLR) with ANN seems to be a good approach.

## 1.3 Significances of study

Firstly, this study is beneficial for the future prediction of hydrological response by taking into account the proposed development of the land at the surrounding of Nerus catchment. In fact, the agricultural area will be expanding by 2020 as stated in the Rancangan Tempatan Daerah Kuala Terengganu dan Rancangan Tempatan Daerah Setiu 2008-2020.

Variations of hydrological responses in watersheds occurred continuously, stimulated mainly by environmental factors, especially climate and land use (Ma et al, 2010; Cuo et al, 2013). Thus, the factors that stimulate changes in the hydrologic response should be analyzed in order to understand and identify the features that occur in a specific manner. Hence, in this study, the used of rainfall-runoff polygon method and k-means clustering method comprising Mann-Kendall trend analysis employed were effective to analyze the characteristics of hydrological responses in Nerus catchment.

Study of the hydrological response in Nerus catchment is important because there is a water intake points located at the up-stream of Sungai Nerus used for the supply of daily water uses of high human population and industry in Kuala Terengganu town. Hence, analysis of the variability of surface water of Sungai Nerus for the more effectiveness water resources and supply for the future sustainability should be carried out.

In order to simplify the physically based models that required the enormous types of data, the Hybrid Neural Network (HNN) as part of Data Driven Modelling (DDM) used to overcome this problem. This study is suitable for a hydrologist, which is trying to find a better, simpler, evaluated and strongly applicable model in water resources management.

This study elucidated the prediction of runoff coefficients using the HNN as the best alternative approaches even it predicted with the leaking of specific field data. HNN models built upon the input and output observations without the detailed understanding of the complex physical laws governing the process under investigation. A great number of the applications in hydrology along with the comparison of their predictive performance with other methods in many studies have been well demonstrated.

In terms of the model, the HNN modelling tool is a site-specific model, which the network structure cannot be transferred to the other area. It is depending on the characteristic of the study area in the aspect of climate and physical watershed characteristics.

A new insight modeling techniques by using HNN modelling approaches will enhance the predictive performance (Corzo, 2009). It is because the single system is not adequate to capture all of the non-linearity characteristics of hydrological response. Hence, combination of several methods reduced the impossibility of capturing all the heterogeneous and fluctuations of hydrological responses.

Other than that, resulting models are able to predict monthly RC as a function of general hydrological response characteristics. It will be a model that predicts long-term mean monthly runoff coefficient given easily obtained climate and land use characteristics. Nevertheless, the results obtained from this study model are valuable to developing monthly RC for effectiveness of application in the Nerus catchment.

## 1.4 Objectives

The main objective of this study is to analyze hydrological response characteristics and develop a new data driven model in Nerus catchment. In order to accomplish this goal, the following specific objectives will be fulfilled:

1. To analyze the characteristics of the hydrologic response;
2. To develop a new hybrid neural network model for runoff coefficient prediction;
3. To evaluate the applicability of runoff coefficient prediction model for the study catchment.

## 1.5 Thesis organization

Overall, this thesis consists of five chapters which purposely to assist in understanding and organized the important topics through the writing process. The chapters in this thesis have been organized as follows:

Chapter 1 of this thesis describes the background of the study, the statement of the problem, the objective of the study and its significance.

Chapter 2 generally discusses about the background of the study, the basic information about study, the general requirements needed in developing discussion. Other than that, this chapter contains the research findings from the journal, books, chapter in books and articles.

Chapter 3 focused on the research methodology. This part contains a brief explanation about the study methodology, location of study area, analysis performed, model development and model evaluation.

Chapter 4 discussed the results obtained from the analysis. This chapter analyzed all the data and interpretation of the results through the proposed methods. Analysis of impact of climate and land use changes on runoff coefficient is well discussed in this chapter. The developed model of HNN and its architecture discuss very detailed in this chapter. Model evaluation also presented in detailed in this part.

Chapter 5 concluded all about the results and the achievement of the objective of the study. It also concluded about the study specifically on the research. It is also the recommendation in improving the quality of the study.

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## PUBLICATION

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