# PHYSICO-CHEMICAL ASSESSMENT OF A TROPICALLY MATURED SECONDARY FOREST CATCHMENT IN ISOLATED AYER HITAM FOREST RESERVE, PENINSULAR MALAYSIA

By

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

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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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**June 2020**

**Chair : Siti Nurhidayu binti Abu Bakar, PhD**
**Faculty : Forestry and Environment**

The presence of isolated forest within rapidly developed areas plays a crucial role in providing water resources, regulating climate, filtering soil and water pollution and might as well acts as mitigator flood events. The main objective of this study is to assess the physico-chemical characteristics from Upper Rasau River Catchment (URRC) of matured secondary forest in Ayer Hitam Forest Reserve (AHFR) during baseflow and stormflow conditions. The physical properties of the streamflow could be categorized to the discharge (Q), turbidity, temperature, and total suspended sediments (TSS) while selected chemical properties particularly are dissolved oxygen (DO), pH, electrical conductivity (EC), salinity, and total dissolved solids (TDS). The 4.66 km$^2$ experimental catchment is located within an isolated granite tropical forest, AHFR in the most developed metropolitan city in Malaysia, Klang Valley. Streamflow from the mature secondary forest catchment (>60 years post-logging) was monitored during baseflow (4-hourly basis) and stormflow conditions (30-minute intervals) from October 2016 until October 2017. River discharges were determined at the outlet of the URRC using average velocity area method, later will be used to developing rating curve. The river water quality was determined based on the National Water Quality Standard of Malaysia (NWQS). The results indicate that the baseflow discharges were ranging from 0.003 to 0.680 m$^3$s$^{-1}$, and from 0.010 to 1.090 m$^3$s$^{-1}$ for the stormevent discharges. Based on NWQS, only pH and suspended sediments fall under Class 3 during stormevents while other parameters were in Class I during both baseflow and stormflow conditions. The climate of AHFR is categorized as equatorial monsoon. The mean temperature is 26.49 °C while total annual rainfall is 2396.4 mm. The findings had providing baseline study which are useful to understand the streamflow behaviour towards physico-chemical properties of the matured secondary forest catchment during less period of rainfall and high period of rainfall.

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

**PENILAIAN FISIKAL-KIMIA TERHADAP KAWASAN TADAHAN HUTAN TROPIK SEKUNDER YANG MATANG DIDALAM HUTAN SIMPAN AYER HITAM TERPENCIL, SEMENANJUNG MALAYSIA**

Oleh

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Keberadaan hutan di dalam kawasan yang dikelilingi oleh pembangunan yang pesat sangat memainkan peranan penting dalam menyediakan sumber air bersih, mengawal iklim, bertindak sebagai penyaring kepada pencemaran tanah dan air, dan juga sebagai mencegah kejadian banjir. Objektif utama kajian ini adalah untuk menjalankan penilaian terhadap ciri-ciri fizikal-kimia yang terhasil daripada Kawasan Tadahan Hulu Sungai Rasau (KTHSR) hutan matang sekunder di Hutan Simpan Ayer Hitam (HSAH) semasa aliran sungai berada dalam keadaan asas dan semasa hujan. Ciri-ciri fizikal sungai boleh dikategori kepada jumlah keluaran air sungai (Q), kekeruhan, suhu, dan jumlah endapan terampai (TSS), manakala ciri-ciri kimia terpilih merupakan oksigen terlarut (DO), pH, pengaliran elektrik (EC), kemasinan, jumlah pepejal terlarut (TDS). Kawasan kajian seluas 4.66 km2 terletak didalam kawasan hutan tropika granit yang terpencil, HSAH di sebuah bandar metropolitan termaju di Malaysia, Lembah Klang. Aliran air sungai yang terhasil daripada kawasan tadahan hutan matang sekunder (>60 tahun selepas pembalakan) dipantau dalam keadaan aliran sungai asas (4-jam sekali) dan aliran sungai semasa hujan (selang 30-minit) bermula Oktober 2016 sehingga Oktober 2017. Jumlah aliran air sungai yang terhasil daripada KTHSR dikira di hilir sungai menggunakan kaedah purata hadlaju air-luas rentas sungai. Kualiti air sungai boleh diklasifikasikan berdasarkan Piawaian Kualiti Air Negara Malaysia (NWQS). Hasil kajian menunjukkan air sungai dalam aliran asas adalah berjulat 0.003 ke 0.680 m3s-1, dan untuk jumlah aliran sungai yang terhasil semasa hujan pula adalah dari 0.010 kepada 1.090 m3s-1. Berdasarkan NWQS, sungai berada pada Kelas 3 hanya untuk parameter pH dan TSS semasa dalam keadaan hujan, manakala parameter lain berada di dalam Kelas 1 untuk kedua-dua keadaan. Cuaca di HSAH boleh dikategori sebgai monsoon khatulistiwa. Purata suhu untuk HSAH adalah 26.49 °C, manakala jumlah hujan tahunan adalah 2396.4 mm. Kajian in memberikan pengetahuan asas

yang berguna bagi memahami perubahan yang berlaku terhadap fizikal-kimia aliran sungai semasa tempoh kurang hujan dan semasa tempoh hujan yang banyak.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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| | |
|---|---|
| AHFR | Ayer Hitam Forest Reserve |
| ALOS | Advance Land Observing Satellite |
| ° | Degree |
| °C | Degree Celsius |
| % | Percentage |
| µs cm-1 | Micro Siemen per centimetre |
| m3s-1 | Metre cube per second |
| AWS | Automatic Weather Station |
| DID | Department of Irrigation and Drainage |
| DO | Dissolved Oxygen |
| E | East |
| EC | Electrical Conductivity |
| EPA | Environment Protection Agency |
| FAO | Food and Agriculture Organization |
| GPS | Global Positioning System |
| $mgL^{-1}$ | Milligram per litre |
| ha | Hectares |
| i.e. | In other words |
| m | Metre |
| N | North |
| na | Not available |
| NTU | Nephelometric Turbidity Units |
| NWQS | National Water Quality Standards for Malaysia |
| ppt | Part per thousand |
| RH | Relative Humidity |

| | |
|---|---|
| s | Second |
| TDS | Total Dissolved Solids |
| TSS | Total Suspended Solids |
| km/km$^2$ | Kilometre per kilometre squared |
| km$^2$ | Kilometre squared |
| mm | Millimetre |
| *i* | Rainfall Intensity |
| ESA | European Spaces Agency |
| DEM | Digital Elevation Model |
| SRTM | Shuttle Radar Topography Mission |
| USGS | United States Geological Survey |
| SW | SouthWest |
| NE | NorthEast |
| MMD | Malaysia Meteorological Department |
| USB | Universal Serial Bus |
| m/s | Metre per second |
| L | Litre |
| UNPD | United Nations Populations Division |
| WQI | Water Quality Index |
| KRB | Kelantan River Basin |
| HNR | Hawkesbury Nepean River |
| DOE | Department of Environment |
| PVC | Polyvinyl Chloride |
| LEDC | Less Economically Developed Country |
| FDPM | Forestry Department of Peninsular Malaysia |
| ARR | Annual Average Rainfall |
| ESD | Ecological Sustainable Development |

| | |
|---|---|
| WHO | World Health Organization |

# CHAPTER 1

# INTRODUCTION

## 1.1 General Background

Both water and forests are linked to each other, as these two are dependent natural resources. It is fitting that the International Day of Forests (March 21) and World Water Day (March 22) fall next to each other, as the health of these important resources often go hand-in-hand. Life cannot thrive without water, as it is crucial to life, the environment, and human development. An ancient Chinese proverb, “To rule the mountains is to rule the water”, shows the general principle that upstream watershed management is the basis to control the downstream.

According to the Food and Agriculture Organization (FAO) of the United Nations, forest areas can be defined as land “spanning more than 0.5 hectares with trees higher than five meters and a canopy cover of more than 10 percent, or the trees are able to reach these thresholds in-situ”. Forests cover approximately one-third of the Earth’s land surface and 10 % of the entire globe (Baumgartner, 1984). Forests help control the hydrological cycle by regulating precipitation, evaporation, and flows. It describes the processes which lead to partitioning of rainfall water into water which returns to the atmosphere via evaporation or evapotranspiration. The forest provides an ecosystem which plays an important role as a supporter to a variety of critical ecosystem processes such as biodiversity, global climate system, wildlife habitat and services to the communities living in or around the forest (Zakaria et al., 2005; Nagarajan et al., 2013). Every acre of the forest has a major influence on water supplies. Both the undisturbed forest and disturbed forest have an influence on the amounts of precipitated water that can percolate through the soil mantle, and this precipitated water can be stored during the wet seasons. This water then becomes available for the streamflow during the dry seasons. The sources will be used throughout the basin. Any other further deterioration of the river’s water quality will affect the ability of the river in providing vital ecosystem services and its ability to support healthy aquatic life in relation to the health of the ecosystem of the basin.

Department of Forestry Malaysia (2018) stated approximately 13 million hectares of the 18 million hectares of forest are managed by the respective forest authorities for timber production or for total protection. In Peninsular Malaysia, these areas are known as Permanent Reserved Forests (PRF). The remaining forest areas are authorised under national parks, wildlife and bird sanctuaries, or state land forests which are subject to future reservation or conversion. Approximately 18 % are made up of the low-lying peat swamp and mangrove forests. The breakdown of the forested areas in Peninsular Malaysia is as shown in Table 1.1.

**Table 1.1: Forest types breakdown in Peninsular Malaysia**

| Type of forest | Area (ha) |
|---|---|
| Permanent Reserved Forests (PRFs) | 4.80 million |
| National Park/ Wildlife and Bird Sanctuary | 0.84 million |
| Mangroves | 0.09 million |
| Peat swamp | 0.25 million |
| State Land | 0.25 million |

Source: (FDPM, 2018)

## 1.2 Problem Statement

Extensive modernization and continuing urban sprawl in Klang Valley region, Malaysia, have caused the disappearing of its invaluable evergreen lowland dipterocarp forests (Chee & Foo, 2011). Most of these forests which once fully functioned as a primary forest ecosystem have been degraded into remnants of secondary forest, fragmented and isolated by the commercial areas or residential area. Most of the time, they were considered as an obstacle for the development and must be removed for providing more land resources in conjunction of the growing population and housing demand. Ayer Hitam Forest Reserve is one of the three remaining lowland dipterocarp forests left in the Klang Valley and surrounded by residential area as well as other economic development which has made it isolated from other neighbouring forests (Nurul-Shida et al., 2014).

Many isolated forests located within a city centre are under pressure to be converted into commercial hub such as agricultural, industrial, and residential areas due to pressing socio-economic development. Malaysia's total population had reached 27.90 million in 2009. In 2020, approximately 80% of the population in Malaysia will be living in urban core areas Klang Valley (EPU, 2010). Drastic development and changes in land use will be required to accommodate the increase in the population. Figure 1.1 shows the different general land use pattern for the Klang Valley in which a large part of the area consists of the urban area, which includes the housing area, industrial and commercial area as well as agriculture area and croplands. Therefore, maintaining the good water resources in the isolated forests within this area is crucial due to high demands on population and the extent of utilisation of natural sources

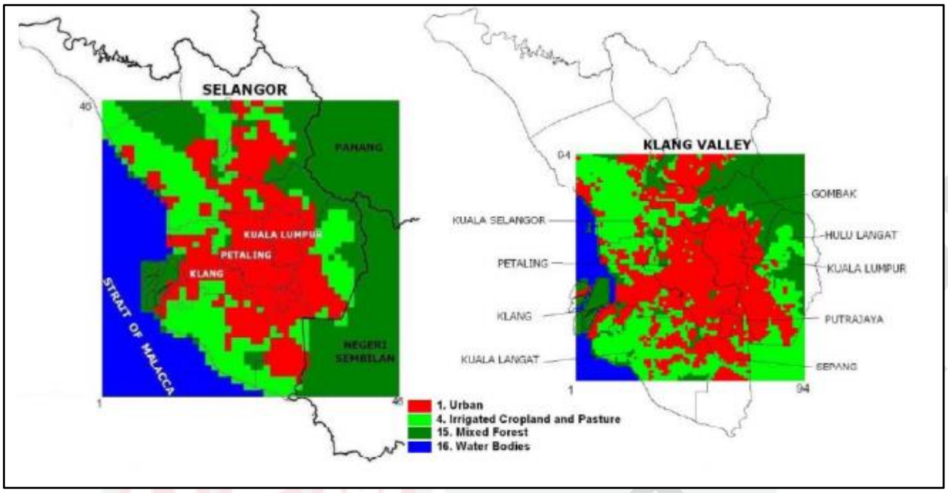


**Figure 1.1: Klang Valley gridded land use map from the Town and Country Planning Department (JPBD) in 3km and 1km resolution.** (Chng et al., 2010; Makmom et al., 2012).

The establishment/restoration/reforestation of abundant land and conservation of isolated forests could possibly contribute not only for water supply but would be useful for flood mitigation. Previous studies such as by Ali (1999) and Yu Abit (2009) and others, have looked at about water quality in the catchment area, but are still lacking in terms of significant values of discharge and quality, especially during stormevents. Besides that, there is a big challenge to access clean and safe water supply, especially in the most developed state. There are many problems related to water resources, such as the water quantity, quality, and timing. Some places might have too little water (drought), while others might have too much water (flooding). The usage of water resources has increased rapidly, and water provision has worsened sharply in most regions and countries (Farda et al., 2015). Unsustainable water use, industrial development, and climate change been pressuring mankind on both quality and quantity (Ceola et al., 2015; Xiao-Jun et al., 2015). These problems will continue to persist, and if there are no mitigation acts, the degradation of streamflow physico-chemical quality and slope failure will most likely to happen in the future. Considering to that, it would be worrying situations in the region, especially with lack of proper planning in land use for forest watershed, which may lead to the problem of insufficient and polluted water supply.

## 1.3 Research Aim and Objectives

The aim of this research is to assess the physico-chemical properties of streamflow in the 4.7 km2 secondary isolated forest catchment. This is conducted by collecting information of the Upper Rasau River Catchment (URRC) and analyse the physico-chemical properties during baseflow and stormflow conditions to understand the behaviour of the matured secondary isolated forest catchment. The specific objectives were:

i. To determine discharge of URRC for baseflow and stormflow conditions.
ii. To characterize the physico-chemical properties in URRC in relation to baseflow and stormflow variations.
iii. To analyse the patterns of suspended sediments using hysteresis loop analysis during stormflow conditions for sediment sources understanding.

## 1.4 Scope and Significant Study

The research described the selected characteristics of baseflow and stormflow and their possible relation to the catchment physiography in the URRC in AHFR, Klang Valley, Peninsular Malaysia. This is the first hydrology study at experimental of 4.7 km2 Upper Rasau River catchment in AHFR conducted for baseflow and stormflow. US EPA (2017) explained terms for baseflow and stormflow to understand. Baseflow was percolated precipitation to the groundwater then moves slowly through substrate before reaching the channel, later will sustains streamflow during periods of little or no precipitation. While, stormflow was from rainfall that reaches the channel over a short time frame through underground or overland routes.

The study was conducted to determine the physico-chemical properties of the streamflow in an isolated forest catchment. To understand the streamflow physico-chemical is plays an important role for growth of animal and plant in water body. The streamflow discharge of the catchment area during the dry and wet periods of the stream was determined, then it was potentially used to develop the rating curve of Upper Rasau River. Both the pollutograph and hydrograph were analysed to understand the forest catchment behaviour during both baseflow and stormflow conditions.

Lastly, in order to understand the suspended sediments movement patterns and the probability of the origin of the sources within the catchment area, hysteresis loop analysis technique was used. The findings would be useful as baseline data for understanding the recovery process of a secondary, logged, and isolated forest catchment area for proper management in mitigation measures of sedimentation issue to ensure the sustainability of local water resources and ecosystem.

## 1.5 Thesis Overview

The thesis is organized as follows. Chapter 1 describes the background study driving to this research. This chapter also outlines the research objectives, scope and significant as well as the importance of the study. Chapter 2 provides a literature review of the tropical forest and uniqueness of Ayer Hitam Forest Reserve (AHFR). This chapter also explain the previous studies of streamflow tropical forest catchment and some analysis that will used in the research. Chapter 3 explains the research site selection and delineation using topographic maps as well as experimental procedure of physico-chemical properties measurements during baseflow and stormflow sampling conditions. Chapter 4 discusses the result and findings obtained for each research objective. Chapter 5 summarizes the achievements and conclusion of this research, alongside recommendation for future studies.

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