ASSESSMENT IMPACT OF LAND USE LAND COVER CHANGES THE WATER YIELD

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ABSTRACT

Quantity is the first attribute of a water service that many people consider. The main source of water is rainfall. Although an eco-system itself does not create the water, it does modify the amount of water moving through the landscape. The main of the study will be assessing the impact of land use and land cover changes to the water-yield. The specific of study will be as follow; to determine the satellite-based water-yield of study area, to determine the satellite-based land use land cover (LULC) changes, and to analysis the relationship between satellite-based water-yield and land use land cover (LULC) changes. Water-yield will be estimate with simple hydrology cycle relationship. Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA) satellite-based monthly rainfalls obtained from public domain were used as input. Meanwhile, actual evapotranspiration were estimate using satellite-based bio-physical index (i.e. Normalized Difference Vegetation Indices (NDVI)) and will use as output. LULC changes also will be determined using satellite-based NDVI. The relationship between satellite-based water-yield and land use land cover (LULC) changes will be statistically analyzed. The result shows, relationship strength between satellite-based water-yield and land use land cover (LULC) changes.

ABSTRAK

Kuantiti adalah sifat yang utama perkhidmatan air yang orang banyak menganggap. Punca utama adalah air hujan. Walaupun ekosistem sendiri tidak menghasilkan air, ia tidak mengubah jumlah air bergerak melalui landskap. Perkara utama kajian ini akan menilai kesan penggunaan tanah dan perubahan penutup tanah kepada hasil air. Perkara khusus kajian adalah seperti berikut; untuk menentukan air hasil berasaskan satelit kawasan kajian, untuk menentukan perlindungan penggunaan tanah dan perubahan penutup tanah berasaskan satelit (LULC), dan analisis hubungan antara air hasil berasaskan satelit dan penggunaan tanah dan perubahan penutup tanah (LULC) . Air hasil akan menjadi anggaran dengan hidrologi mudah kitaran hubungan. Hujan Tropika Mengukur Misi Multi-satelit Analisis Pemendakan (TMPA) hujan bulanan berasaskan satelit yang diperolehi daripada domain awam telah digunakan sebagai input. Sementara itu, evapotranspirasi adalah anggaran menggunakan bio-fizikal indeks berasaskan satelit (iaitu Perbezaan Ternormal Indeks Tumbuhan (NDVI)) dan akan digunakan sebagai output. Perubahan LULC juga akan ditentukan menggunakan berasaskan satelit NDVI. Hubungan antara penutup air-hasil dan penggunaan tanah berasaskan perubahan satelit (LULC) akan dianalisa secara statistik. Hasil kajian menunjukkan kekuatan hubungan antara hasilan air berasaskan satelit dan penggunaan tanah dan perubahan penutup tanah (LULC).

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LIST OF ABBREVIATIONS

AET	Evapotranspiration
ET	Evaporation
ETo	Potentional Evaporation
GIS	Geographic Information System
GPCP	Global Precipitation Climatology Project
HDF	Hierarchical Data Format
JMM	Jabatan Meteorologi Malaysia
JPS	Jabatan Pengaran dan Saliran Malaysia
LULC	Land Use Land Cover
MODIS	Moderate Resolution Imaging Spectroradiometer
NASA	National Aeronautical and Space Administration
NDVI	Normalized Difference Vegetation Indices
Tiff	Tagged Image File Format
TMPA	TRMM Multisatellite Precipitation Analysis
TRMM	Tropical Rainfall Measuring Mission

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Quantity is the first attribute of a water service that many people consider. It constitutes the amount of water available for drinking or agriculture or describes the volume of flood waters. For services such as water supply, an increase in quantity is beneficial; in flood mitigation decreasing quantity is beneficial. Although an ecosystem itself does not create the water, it does modify the amount of water moving through the landscape.

Water is one of the most important of natural resources for all living things. In certain areas, water tends to be very limited area and there are situation where the availability of water is always deficient. This phenomena will altered by the effect of global warming. Water also used for transportation, sources of power, and serves many other useful purpose for domestic consumption, agriculture and industry. The main source of water is rainfall. The amount or availability of water for various purposes is very much depending upon the amount of precipitation in that particular area. Excess or extended absence of rainfall will cause flooding and drought respectively. Adler et al., (2000) stated that precipitation information is essential to understanding the hydrologic balance on a global scale and in understanding the complex interactions among the components within the hydrological cycle.

Rainfall and actual evapotranspiration (AET) is meteorological parameters that are influenced by climate, topography, and the land use land cover. Over the years, with various remote sensing algorithms have been used to determine the quantity of spatial and temporal variability of rainfall (Dinku *et al.*, 2007; Islam and Uyeda, 2007; Jamandre dan Narisma, 2013) and actual evapotranspiration (AET) (Nutzmann and Mey, 2007; Zwart and Bastiaanssen, 2007; Li *et al.*, 2008; Teixera *et al.*, 2009) with wide coverage.

1.2 PROBLEM STATEMENT

The information of water yield is very important for the sustainability of the planning and security monitoring of water resource. The rainfall and evapo-transpiration relationships are often used for general assessment of water yield. However, the climate change and the land use are the eco-hydrological responses that impact the spatial and temporal variability of water yield information (Brauman *et al.*, 2007).

Over the years, bio-physical index's were used to map land use land cover (LULC) using satellite image. Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA) satellite-based monthly rainfall obtained from public domain were used as input. Meanwhile, actual evapo-transpiration were estimated using satellite-based bio-physical index (i.e. Normalized Difference Vegetation Indices (NDVI)) and were used as output. LULC changes also will be determined using satellite-based NDVI. Ali, M.I. (2014), found that satellite-based water-yield comparable with observation dataset water-yield. Therefore, satellite-based water-yield and LULC map could be used in this research.

1.3 OBJECTIVES OF THE STUDY

The main of the study was assessing the impact of land use and land cover changes to the water-yield. The specific objectives of this research were as follow:

i. To determine the satellite-based water-yield of study area
ii. To determine the satellite-based land use land cover (LULC) changes.
iii. To analysis the relationship between satellite-based water-yield and land use land cover (LULC) changes

1.4 SCOPE OF THE STUDY

This research study considers the following conditions:-

i. Study conduct for period of 5 years (July 2009-June 2014).
ii. This research uses rainfall data derived from satellite image data Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA). Literature review found that many previous research using such data, and easily obtained from the public domain
iii. This research use Normalized Differential Vegetation Index (NDVI) satellite images obtained from the public domain to publish actual evapotranspiration (AET).
iv. Publishing process field data relational model and satellite images as well as validation data, rainfall data, pan-evaporation and evapotranspiration field derived from Jabatan Meteorologi Malaysia (JMM), Jabatan Pengairan dan Saliran, Malaysia (JPS) and reports from the literature review

1.5 RESEARCH SIGNIFICANCE

Research must be conducted on the use of satellite image data, which is capable of estimating rainfall and actual evapotranspiration field, and then estimate the water yield and its effects as a result of the diversity of land use land cover (LULC) and climate of an area can be done. This is because some of the advantages that have been identified, there are:

- Water yield issues from both satellite imagery data, is a synoptic view. They provide the information of water yield based on the change of land use land cover in a detailed area.
- Data sources area available in the computer networking and only requires the cost to download.
- Satellite image data is a digital format. With the help of technology Geographic Information System (GIS) and easy connection of the water

balance, the publication of water yield of an area can be done more quickly. It is very suitable for practical applications.

- Satellite image data can provide continuous information on the ground compared to a discrete data field.
- Water yield from both the satellite image, can estimate the product water basin that no has information runoff discharge rates.
- Water yield from both the satellite image, can be used as a check on the information from the gauges runoff discharge rates. This is very useful for detecting changes in a basin runoff (Noraida, 2009; SUK, 2011).

1.6 THESIS STRUCTURE

The thesis is divided into five (5) chapters. Chapter One describes the background and objective of the study is to be achieved. While chapter two, looking back at the previous research studies related to the review of progress. In Chapter Three, the water products study described the process of determination of the distribution of the monthly rainfall data and monthly AET based on satellite images, which will be a key component of the water balance analysis. Furthermore, the determination of the distribution of water products and information accuracy analysis effected. The publication of a map of the distribution of rainfall, AET, water yield information and applications in the study area and validation with previous reports are shown and explained in Chapter Four. Chapter Five is the conclusion of the study and recommendations for future research

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Water yield is readiness of water resources for runoff and water storage of soil or groundwater after deducting for evapotranspiration (Brauman et al., 2007). Langbein and Kathleen (1995) also defines that the amount of readiness of water resources or the difference between rainfall and water loss (it is evapotranspiration). According to Hyperdictionary (2009), water-yield known as the running water out of the whole or part of the basin (or region) either through surface or sub-surface aquifer within the time period be given (example one year). Meanwhile, the combined of runoff is the runoff river discharges, runoff and groundwater runoff. For a small basin, the value of measurement of runoff discharge River, give accuracy of water yield, which is also the result of a combination of hydrological and meteorological processes in the basin.

Although the basin ecological system does not produce its own water, it is able to vary the amount of water through the landscape of the basin (Brauman et al., 2007). Quantitative evaluation of product information as well as water amendments, the effects of climate change and human activities, can do using a basin of water balance analysis. Furthermore, the evaluation of water resources to a region, the territory and the continent can be obtained (Sokolov and Chapman, 1974). Based on studies by previous researchers, water balance analysis provides a good frame to study hydrology of the area. Imbalance that exists, is leading to the identification and description of hydrological processes and better measurement techniques.

In addition, various hydrological models are derived from the water balance equation. Hydrological model is a mathematical model to transform input elements such as rain water runoff or runoff river discharge. It can be a simple concept model to model complex physical. Rainfall-runoff model was used for a variety of uses, from livestock-water basins to estimate the impact on its characteristics as a result of changes in cover and land use and climate change (Singh and Frevert, 2002). The model is calibrated in a basin with a record of river runoff discharge. Then, the model was used to estimate outcomes and changes in water basins that do not have information runoff discharge rates. Two zoning procedure often used, first, to the nearest model of the basin, and second, the model of the basin that have similar characteristics are used as a reference for predicting the changing landscape of the basin system that does not have such information

Furthermore, determination information of water yield in this study is focusing on the use of satellite image data as a source of information on both main components input (rainfall) and output (AET). For the purposes of this study, research literature is divided into three main parts. There are, first determination of water yield with the water balance analysis as well as the effect of changes in land use land cover, second determination of the distribution of rainfall from satellite image data, and third determination of evapotranspiration (AET) from satellite image data.

2.2. DETERMINATION OF WATER YIELD WITH THE WATER BALANCES ANALYSIS AND THE IMPACT OF LAND USE LAND COVER (LULC) CHANGES.

Water balance analysis has been used for a variety of uses, to estimate from basins water yield and the impact on its characteristics as a result of changes in cover and land use and climate change

2.2.1. Hydrological Cycle and Water Balance Analysis

The hydrological cycle is the most fundamental concept for any water engineer. The hydrological cycle, which is depicted in Figure below, shows how water finds it way from the sea to the atmosphere, to the land, to the river, and back into the sea. Depending on the scope of the engineer the focus is on a specific part of the hydrological cycle. For example, someone who is interested in polder behaviour needs specific information on rainfall, evaporation, seepage and inflow and out flow discharge of the polder area. But it is not interested in how the discharged polder water is transported to the sea. On the contrary, a hydraulic engineer does not focus on the polder system. It especially wants to know how river water is transported to the sea. It focus is more on sedimentation process and fluid dynamics.

The water balance is defined by a general equation, which is the legal statement of hydrological eternity mass (law of conservation of mass) as used in the hydrological cycle. The equation is (Sokolov and Chapman, 1974) ;

Inflow = Outflow + Changes of storage (2.1)

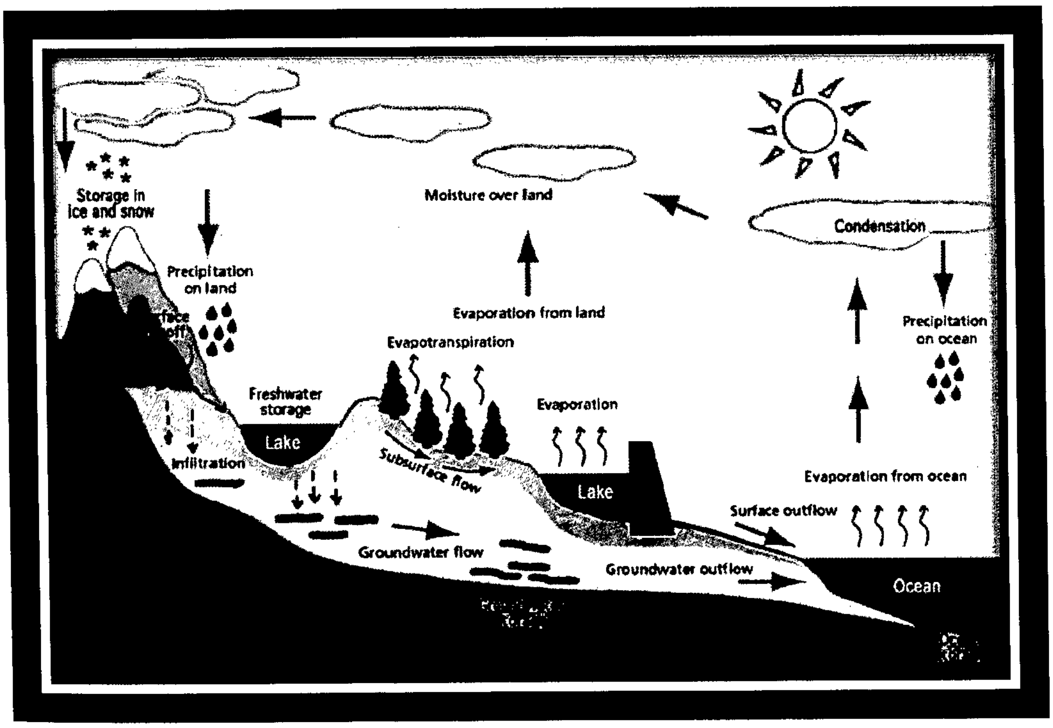

Figure 2.1: Hydrological Process

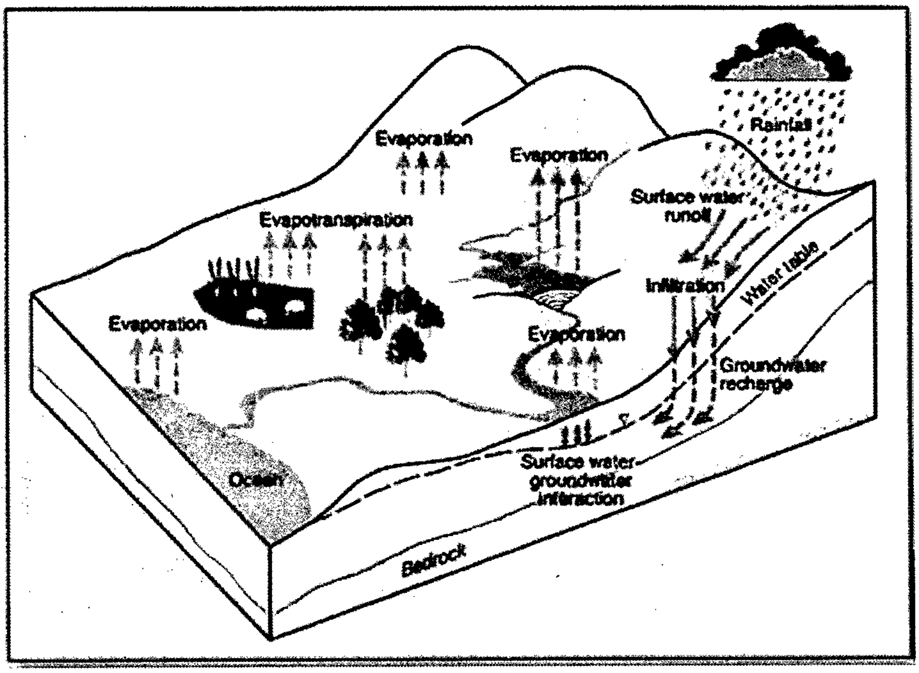

Figure 2.2: Schematic diagram of partitioning of the water balance components

In hydrology, water balance equation can be used to clarify water flow in or out of a system. There are four (4) characteristics as follows;

a. Water balance can evaluate the hydrological cycle at any subsystem, any size and any intervals.
b. Water balance can be your browser whether all components of the flow and savings were taken into account in environmental engineering.
c. Water balance components can calculate unknown at the water balance equation, when other components are known with good accuracy.
d. Water balance can be used as a model for the complete process hydrology. This means it can be used to forecast the impact of changes to the components on the other components in a system or sub-system.

With the features outlined above, the water balance is a way of solving a vital part in theoretical and practical hydrology. Based on water balance analysis approach, enabling quantitative evaluation on water resources and the changes of water resources as a result of human activities. Current information on the water balance of the river and the Lake for a short interval (monthly, week of the season, and daily) is used for water storage operations management and hydrological forecasts for water management (Sokolov and Chapman, 1974).

The water balance equation can be described as follows (Sokolov and Chapman, 1974; UKRAINE, 1989);

$$P = ET + Q + L + \Delta WS + \Delta G \tag{2.2}$$

Where:

P = precipitation

ET = evapotranspiration

Q = runoff

L = depth/inactive groundwater

ΔWS = changes in soil moisture storage

ΔG = changes in underground water storage

The components involved in the equation of water balance depends on two (2) of the following; 1) time period and 2) the flow domain. The water balance is always evaluated in the annual average, the calendar year or the calendar year hydrology. The flow domain is divided into two (2), that is, a) a flow domain consists of physical entities (such as river basin), and b) a flow domain consisted only of some physical entity (such as an irrigation scheme). In the river basin, Border divider overlap basin with underground water. Considered a border, there is water impermeable underground water crossing the divider. At the outflow of a river basin, water impermeable boundaries almost surface land has prevented groundwater out, making all the water from the river basin flow as the flow of the river. Take the period of the calendar year; changes in water storage can be ignored. In line with UKRAINE (1989), the value of L is ignored, while the value of Δ and Δ G not WS considered. Equation (2.2) is moderated to;

$$P = ET + Q \tag{2.3}$$

This is in line with the study of Zhang et al. (2001) also found that, if the basin has water resources limited (water tight) and topography (topographic divide) overlap with the distribution of underground water (groundwater divide), after a long period (5 to 10 years), it is reasonable to consider it to be an underground water storage changes (Δ G) and changes in humidity storage land (Δ WS) is there. Therefore, ET along with the rain (P) and runoff (Q) control the availability of water in the Earth's surface (McCabe and Wood, 2006). An accurate estimation of ET real impact, by specifications in the water balance for the next sub-basin and basin (Cleugh et al., 2007). It also provides information to the water resources management; I) use of water resources, and ii) productivity of water use water in production of biomass per unit water (Steduto et al., 2007).

2.2.2. Hydrological Model

Cost constraints to provide and maintain the runoff rate gauge the expression for each basin, hydrological model is published. Hydrological model is a mathematical model for input elements such as happiness to rainfall runoff or runoff of river discharge. Increase power computing have seen the development of rain-runoff model for simulation and forecasting of natural hydrology. The main objective of hydrological models is to provide reliable information for planning and management of water resources through understanding of hydrological processes and their interactions. Modeling of any kind can be seen as a system that transforms inputs into outputs, for example, models UH which is a linear transformation to rainfall runoff (Duband et al., 1993).

Rainfall-runoff model is a mathematical model of hydrological systems natural very complex and have uniformity space and temporal (Pitman, 1973; Beven, 1989). Often, it is not possible or practical to represent hydrological systems in detail, and assumptions are often made. This is done for a number of reasons, including the lack of data and all the factors and processes that affect the behaviour of the system is not completely understood (Beven, 2000a). There are many different models in hydrology, different development or degree of complexity (e.g., Singh, 1995). The model can be distinguished based on the characteristics of the clear differences such as stochastic compared to deterministic concept compared to physical-based, and clotted than the distributed model (Clarke 1973). The main policy difference between the models is a model stochastic and model deterministic. Model of data-based model stochastic is and some randomness or uncertainty in the resulting output simulation method of variable randomness in the input, while the deterministic model is a model based on the process and consider a single prediction for all output variables generated from a sequence of inputs and the process are defined physically without random component (Beven, 2001).

Rainfall-runoff models have been classified, based on their structure as either black box model (empirical), grey box (the concept), or white boxes (physical-based) (Clarke 1973). Empirical models only represent the numerical relationship between output and input without the need to understand the process. Examples of these are model linear regression, the relationship between the amount of runoff and rainfall depth (Kekkonen and Jake man, 2001). On the other hand, the physical model is based on thermodynamics, conservation of mass, momentum and energy as the equation St. Venant (Beven, 2002a). These models assume basin as variability system space and processes involving hillside across the basin can be modelled (Beven, 2001, 2002a). Between the two models, empirical models and physical models, there is a concept model requires understanding of hydrological processes include the formulation of the model. The model concept, basin is considered to be made up of some moisture storage where the rainfall input channelled through the process of moisture, eventually to produce output of the runoff of the River, all these elements are represented clearly by the mathematical relationship (Beven, 2001)

Rainfall-runoff models are also classified based on the scale in which they represent the hydrological basin system, that is, whether clotted or distributable naturally (Todini, 1988). With the cumulative model, basin is considered to be one unit and rain as a single input related to the output stream water run without taking into account the diversity public process and the characteristics of the River Plate Basin (Szymkiewicz, 2002). As an alternative, with a distributed model, an attempt is made to take into account the reaction of hydrological processes variability space in the basin, which is considered as a discrete unit (Abbott et al., 1986; Abbott and Refsgaard, 1996; Beven, 2001)

Rainfall-runoff modelling effective starting in the 1880's with the development of the ' rational method ' related river runoff directly to the input size, rainfall and basin runoff coefficient (Smith and Lee, 1984). The difficulty of using this method is to make a decision on the value of the coefficient of runoff because this parameter will be different from the basin. In 1960, accumulated more complex models have been developed to clearly reflect the perception of the hydrology of the hydrological response process to input from the rain. This leads to the approach of UH (Dooge, 1959) who try to forecast the time distribution of discharge and its linear estimates process. Although this approach helps the hydrology properly, linear assumption approach UH has greatly criticized for hydrological response process was not to rain (liner Dooge, 1979; Bates and Davies, 1988). This saw the introduction of the concept of cumulative to take into account the relationship of rainfall-runoff not linear, especially when the computer began to be widespread in between the 1960s and 1980s. one of the earliest examples is the model such as the Stanford Watershed Model (Crawford and Linsley, 1966; Görgens, 1983), which is the cumulative model clearly take into account the slowdown in the land because it represents the hydrological processes and basin storage (moisture on the ground, soil moisture and groundwater) with some elements. Runoff between this storage is controlled by different parameters, which requires certain application data to calibration (Beven, 2001). These models differ in terms of the number of parameters, from the simple (Roberts, 1979; Diskin et al., 1973) to more complex structures (Crawford and Linsley, 1966). However the model simple is often favoured because they have some parameters require calibration and capability are often the same as obtained from using complex models (Young et al., 2006). Another example is the concept model Sacramento (Burnash, 1995), HBV model (name Sweden Sweden Meteorology and Hydrology Institute, where the model is developed) (Bergström 1995) and model Pitman (Pitman, 1973). Model semi-distributed as Soil Water Balance Model (SWB) (Schaake et al., 1996), taking into account changes in parameters space but maintaining structural basin easier. The constraint of this strategy is that each sub-basin will require a set of values of the parameters and input estimation.

In contrast to the conceptual model, where the parameter is often estimated by field observation data of calibration, distributed model measured physical parameters directly from the physical properties of the basin. Basin (Binley et al., 1991; Moreda et al., 2006). Distributed model, however little physical advantage taking into account changes in some process parameters necessary for accumulating because the scale of the model is usually greater than the scale of operation of the various hydrological processes (Beven et al., 1988). Crucial differences between the model concept and model of distributed physical parameters of physical model can be validated with field measurements and generally more suitable for the basin no data responses of hydrological processes. Model of distributed physically better suited in the basin no data responses of hydrological process because their bases are physical information process in the basins (Abbott et al., 1986). However, the main drawback of the model practical because the amount of input data required and complex (Beven, 1989; Binley et al., 1991). A physical model distributed was famous TOPOMODEL model (Beven et al., 1995), MIKE SHE model (Rafsgaard and Storm, 1995) and model SWAT (Arnold, 1992).

While there are various models of rainfall-runoff, problems arise for choice model for practical use. The user models often choose a model that easy to operate but represent important hydrological processes (Butts et al., 2004). Therefore, semi-distributed approach model to bridge the gap between a simple models clotted and model complex distributed are the most liked. In this regard, Beven (2001) summarizes a number of basic criteria for choosing the model including the availability model, input data requirements, the ability of the model to make predictions and assumptions related. However, he has claimed that some compromise must be met if the criteria to be used for practical use.

In the practical assessment of water resources, the scale of hydrological model is used and the resolution of input data, both have space and temporal, in turn has a major influence on the structure of the model (Klemeš, 1983; Schaake et al., 1996). With regard to the scale of space, natural process aspects important at one scale may not be connected at the other and therefore models can be lean to scale (Beven, 1995; Blöschl and Sivapalan, 1995). Inevitably, more complex model requires more detailed data, measured on a scale that is more subtle, simple data model requires less detail, averaged on a wider scale (Koren et al., 1999). For a complex model, will not provide benefits exceeding what can be supported reliably by existing data (Perrin et al., 2001). On the other hand, simple model requires simple input is often not sufficient to detect all hydrological processes that need to be (Wood et al., 1990). The temporal scale is described in step-time for model and simulating behaviour of hydrological systems over a period of time with rain-runoff models, this range an hour, annual, several decades or more. Period of time also affect the complexity and it is seldom viable to use very complex model for a longer period of time, often due to a lack of climate data, measured at shorter time (Finnerty et al., 1997). Therefore, a balance is needed between the available data, the complexity of the model and the desired output from the model.

History of rainfall-runoff models have evolved over the decades from simple empirical concepts, model next model complex physical (Dooge, 1959; Binley et al., 1991), and return to the simple model (Perrin et al., 2003). This is largely due to the search for appropriate modelling tools to achieve specific objectives. The concept of the appropriate means to develop the model and choose the model with a level of complexity which reflects the real needs for modelling results (Jakeman and Hornberger, 1993). To understand the hydrological processes, the ability of the model to describe them is important (Beven, 1989). Reliable forecasts can only be achieved by the model using a set of parameters that reflect the basic mechanisms involved in the basin (Beven, 1989). The main problem related to the complex model is relative to the availability of data, the choice of the function of objectives and related problems in identifying the structure of the selected model and estimate the parameters (Yew Gan et al., 1997). These issues are still the biggest obstacle to the success of the use of models to estimate the water resources in the basin have rate information runoff discharge or not.

2.2.2.1. Calibration Model

Rainfall-runoff model is represented in simple real world, which means that the parameters are the aggregate of the hydrological basin using the diversity process of empirical relations (Beven et al., 1995). Therefore, all models (either simple or complex physical concept) which is usually with the data measured in the field to identify appropriate model parameters with the given (Beven and Binley, 1992). This is because there is no measurement technique that allows direct measurements and estimates for parameter values on the scale required by the model (Klemeš, 1983; Abbott et al., 1986). There are two classifications of existing model parameters, i.e. parameters calibration arising in the empirical relations and calibration from data climate and runoff data, measured, and physical parameters-based essentially measured or estimated directly from the measurement in the basin. Limitations of using physical-based parameter is the dependence on the scale and quality of this parameter information obtained (Beven, 1989). The focus of the discussion in this section was at calibration parameters. The main reasons for calibration model are three: to take into account the impact of hydrological conditions in certain sub-basin, to adjust the bias in climate data input (such as measurement error rain, variability space and temporal), and most importantly, to take into account the physical characteristics of the basin (land and plants) which is not very uniform and basically not or at least less known (Blöschl, 2006).

Have often suggested or implied in the literature review that the data used for the hydrological model should represent calibration various phenomena experienced by basin (Beven and Binley, 1992; AO et al., 2006). In view of the limitations of the information river runoff, as well as the constraints of the structure of the model, it is often difficult to achieve unique solutions (Beven, 1993). In practice, climate and river runoff necessary to find suitable parameters for existing conditions in basin, often not reliable. River runoff data can have a record of lost and short, in addition to the effects of development (for example, dams or irrigation systems) to be taken into account before using a model designed to simulated natural state, while rainfall data may be rare, or wholly unreliable because error measurements. In General, there is no agreement about the best way to hydrological models, because calibration which cannot