QUANTIFY OF WATER-YIELD FROM SPACE – SUNGAI PAHANG WATERSHED

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Thesis Submitted in Fulfillment of The Requirements

For The Awards of **B.ENG (HONS.) CIVIL ENGINEERING.**

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UNIVERSITI MALAYSIA PAHANG

JUNE 2014

ABSTRACT

Water-yield information is vital for water resources sustainability planning and security monitoring. Over the years, flow-rate gauges have been used to determine the flow of water as water-yield information from watershed, the result of hydrometeorology variability and human activity. The issue is flow-rate gauge information hard to obtain, especially during flood season. The main objective was to quantify water-yield information using simple hydrology cycle relationship, through fully satellite-based data sources as input at Sungai Pahang watershed. The specific objectives of the study were as follow; to establish database of satellite-based rainfall and actual evapotranspiration map, and to quantify water-yield using simple hydrology cycle relationship. Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA) and Moderate Resolution Imaging Spectro-radiometer (MODIS) bio-physical index satellite data were downloading from public domain resources to produced rainfall and actual evapotranspiration map, respectively. Both maps were used as input in hydrology cycle relationship to quantify water-yield information of study area. The results show that, satellite-based water-yield able to shows changes based on season. Therefore, satellite-based water-yield could be able as an alternative source of watershed water-yield. In the future, to get reliable results, it is necessary for those data to be validated.

ABSTRAK

Maklumat hasil air adalah penting untuk perancangan sumber air dan pemantauan keselamatan. Selama bertahun-tahun, tolok kadar alir telah digunakan untuk menentukan aliran air seperti maklumat hasil air dari kawasan tadahan air, hasil daripada kepelbagaian hydrometeorology dan aktiviti manusia. Isunya ialah maklumat kadar aliran tolok yang sukar untuk didapati, terutamanya semasa musim banjir. Objektif utama adalah untuk mengira kuantiti hasil air menggunakan hubungan mudah kitaran hidrologi, melalui sumber-sumber data berasaskan satelit sebagai input Sungai Pahang yang bermakna. Objektif khusus kajian ini adalah seperti berikut, untuk menghasilkan pangkalan data hujan berasakan satelit dan peta sebenar penyejatan, dan kuantiti air hasil menggunakan hubungan mudah kitaran hidrologi. *Tropical Rainfall Measuring Mission Multi-satellite precipitation Analysis (TMPA)* dan *Moderate Resolution Imaging Spectro-radiometer (MODIS)* indek bio-fizikal data satelit telah dimuat turun dari kedua-dua sumber awam untuk hujan dihasilkan dan sebenar Peta Semasa musim kering. Kedua-dua peta telah digunakan sebagai input dalam hubungan kitaran hidrologi untuk mentafsirkan data hasil air di kawasan kajian. Keputusan menunjukkan perubahan berdasarkan musim. Berasakan satelit, hasil air yang didapati sebagai sumber alternatif bagi kawaan tadahan hasil air. Pada masa akan datang, untuk mendapatkan keputusan yang boleh dipercayai, adalah perlu untuk membuatkan perbandingan bagi mendapatkan data yang tepat.

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Water-yield information is vital for water resources sustainability planning and security monitoring. Malaysia has experienced a series of unprecedented water crisis in the Klang Valley in year 1998, largest settlements area. Throughout the Klang Valley water rationings were occurring, since the water level in main reservoirs (i.e. Klang Gates, Batu and Semenyih dams) reduced and almost dry.

Water-yield is defined as the amount of water resource availability or the difference between rainfall and water loss. From concept, actual-evapotranspiration (AET) is the foundation of the loss of water (Langbein and Kathleen, 1995). Water-yield is also known as the outflow of water from the whole or part of the basin (or region) either through the surface or sub-surface aquifers in a given time period (eg one year) (HyperDictionary, 2009). Quantitative assessment of water-yield information changes, the effects of climate change and human activities, can be done using a water balance analysis of the basin.

Further, the assessment of water resources for a region, province and continent can be obtained (Sokolov and Chapman, 1974).

Water balance is water accounts for a basin, region or for the whole world, taking quantitative hydrological cycle. In the hydrologic cycle, rainfall that reaches the soil surface (ie drainage, rivers, lakes) will be surface water, or filtered into soil moisture or water seeping into underground storage. Further, is released into the atmosphere through evaporation (from the soil surface, lake, river, sea) and transpiration (the plant). How rainfall is distributed to the hydrological components (ie, runoff, soil moisture, groundwater), depending on space and temporal variability in rainfall and surface characteristics (Figure 1.1).

Over the years, remote sensing technology has been used to provide information such as the distribution of the components of the hydrological cycle of rainfall (eg Dinku et al., 2007; Islam and Uyeda, 2007; Jamandre and Narisma, 2013) and AET (eg Nutzmann and Mey, 2007; Zwart and Bastiaanssen, 2007; Li et al., 2008; Teixeira et al., 2009) with a broad coverage. It is also capable of providing spatial and temporal variability of such information, the impact of response to climate change and land use on an ongoing basis. With the help of technology geographic information system (GIS), the information is a continuing phenomenon, easily analyzed and displayed.

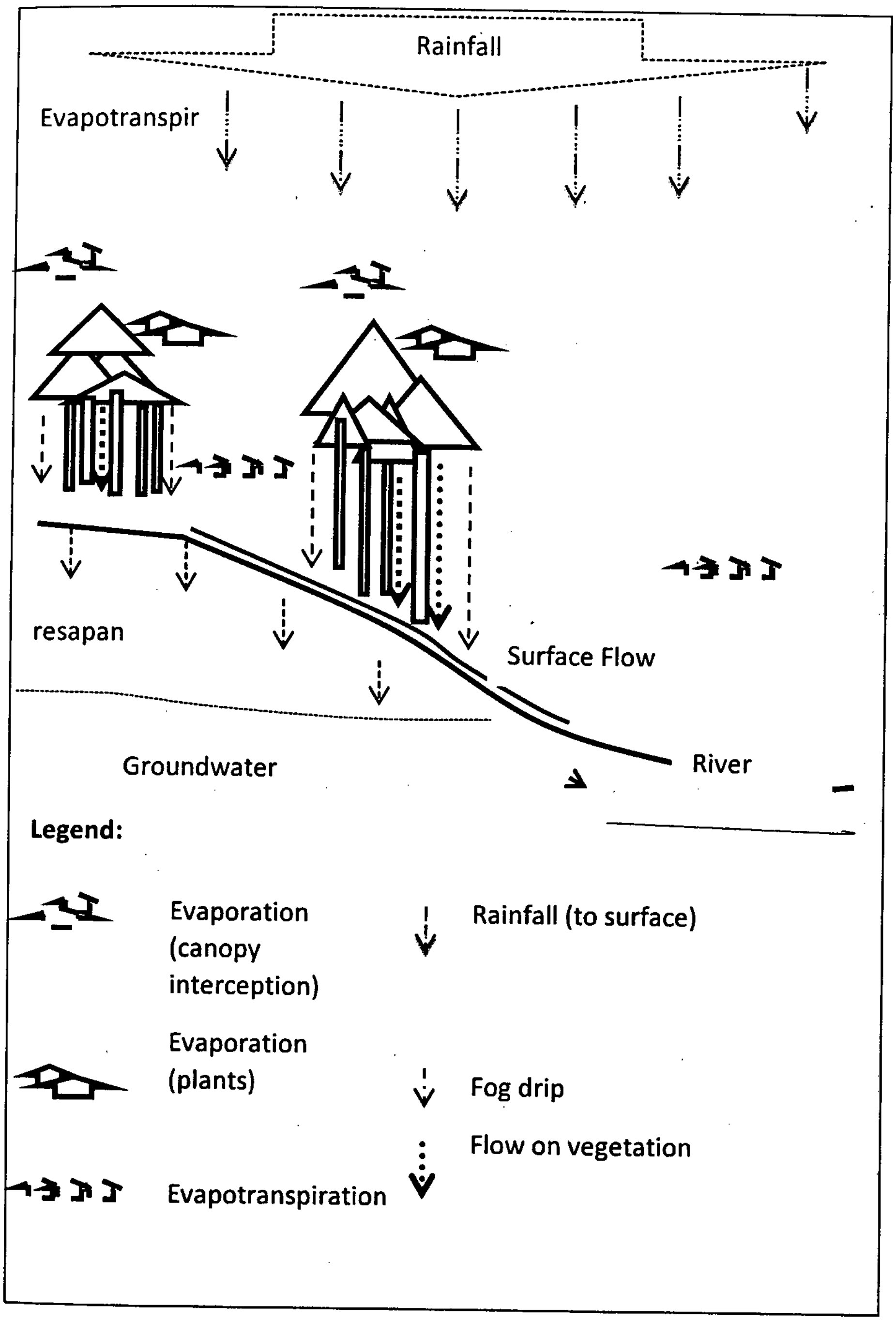

Figure 1.1 : Hydrology Cycle

Droogers et al. (2009) used remote sensing technology to obtain information of rainfall and AET, for the purpose of analyzing the sources of water for the water planning in Egypt, Saudi Arabia and Tunisia. Analysis using rainfall and AET, respectively derived using satellite image data Tropical Rainfall Measurement Mission (TRMM) satellite image data and algorithms with the Surface Energy Balance Algorithms for Land (SEBAL). However, the TRMM satellite image data can not be used directly. It should be a process of calibration and validation specific to an area in advance, so as to reduce error on the published estimates of rainfall (Aghakouchak et al., 2009). To use an algorithm called resentful physical algorithms in turn, require daily weather data (ie, wind velocity, humidity, solar radiation and temperature), digital elevation models and the crop coefficient. In addition, satellite imagery net of any cloud cover the whole area required for the purpose of processing the energy balance (Verstraete and Pinty, 1992).

1.2 PROBLEM STATEMENT

The quantification of water-yield is extremely difficult over large spatial and temporal domains through direct observation. The sign and magnitude of water-yield changes in the climatic variables vary by location and time historical studies. Therefore, hydrologic change in response to climate change and variability is expected to be highly variable in space and time, and large uncertainty exists.

Over the years, flow-rate gauges have been used to determine the flow of water as water-yield information from watershed, the result of hydrometeorology variability and human activity. The issue is flow-rate gauge information's hard to obtain, especially during flood season. Management of water resources become more effective with regard to meteorological information (ie rainfall and AET), and hydrology (ie water flow rate) is good for a long period of time. However, this situation has always been difficult due to the availability of data distribution of rainfall and AET is limited and the absence of water flow rate gauge. However, determining the spatial and temporal variability in rainfall distribution and water products AET further information quantitatively and objectively a basin, it is necessary for sustainability planning and monitoring of safety (eg loss) of water. Remote sensing satellite missions over the past decade has seen great success in sharing data, especially for applications related to environmental management and natural resources. Among them is the TRMM satellite data and MODIS (Moderate Resolution Imaging Spectroradiometer).

The study will attempts to answer the following research question: How to quantify the spatial and temporal variability of water-yield information through full satellite based data sources in Sungai Pahang watershed.

1.3 OBJECTIVE OF STUDY

The main objective of this study was to quantify water-yield information using simple hydrology cycle relationship, through fully satellite-based data sources as input at Sungai Pahang watershed. The specific objectives of the study were as follow;

1. To establish database of satellite-based rainfall and actual evapotranspiration map, and
2. To quantify water-yield using simple hydrology cycle relationship.

1.4 SCOPE OF STUDY

1.4.1 Study Area - Sungai Pahang

The Sungai Pahang watershed is located in the Malaysia Peninsula between latitude 2° 48'45" - 3° 40'24" N and longitude 101°16'31" - 103° 29'34" E. The basin has a total area of 29 300 km² which is lies within Pahang (which is about 75% of the State) and 2,300 km² is located in Negeri Sembilan. The length of the river is estimate to be 459 km and it is a confluence of the Sungai Jelai and Sungai Tembeling from the upstream which join together at Kuala Tembeling, about 304 km from river mouth at east coast of Pahang state on the Tahan Mountains and drains into the South China Sea.

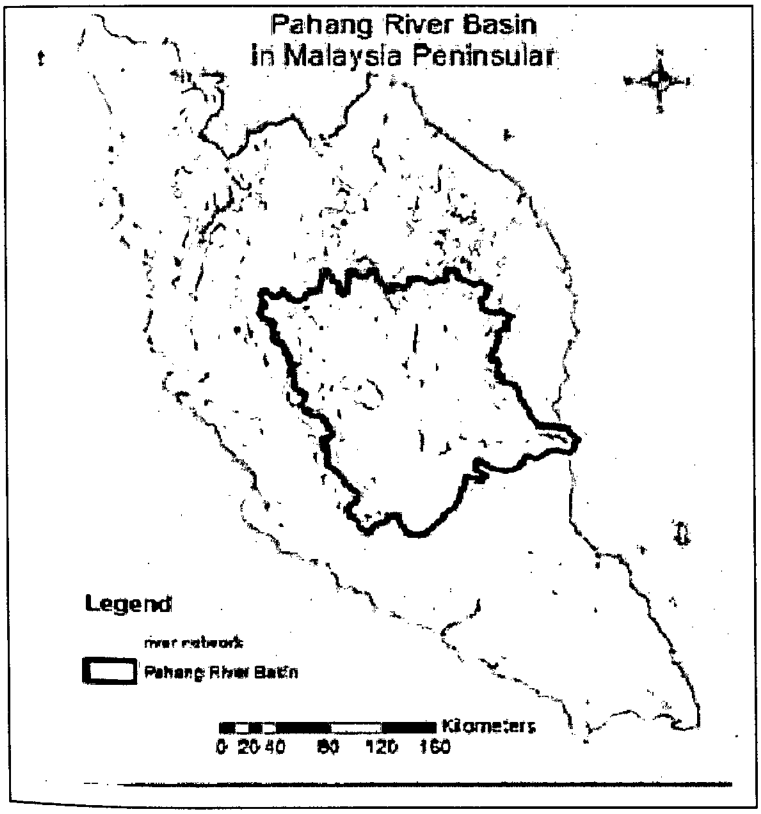

Figure 1.2: Sungai Pahang Watershed

Table 1.1: Basic information about Sungai Pahang Watershed

Name : Pahang river		
Location	2° 48' 45" to 3° 40'24" N	101° 16'31" to 103°29'34" E
Area : 29 300 km²	Length of main stream : 459 km	
Origin : Mountain Tahan (2 187 m)		
Outlet : South China Sea	**Lower point : river mouth (0 m)**	
Main geological features : shale, Mudstone, Limestone and rooks		
Main tributaries : Tembeling River (5050 km²), and Jelai River (7320 km²)		
The main reservoirs : southern Abu Bakar Dam of TNB, Chini Lake and Bera Lake		
Mean annual Precipitation : 2 170 mm (1971-2002)		
Mean annual runoff : 596 m³/sec at Lubok Paku (1973-2002)		
Population :1,000,000	**Main Cities : Kuantan**	
Land Use : Virgin Jungle, Rubber, Paddy, Oil palm, other agricultural crops, Urban		

Source: catalogue of river UNESCO

Table 1.2: Characteristic of river and main tributaries

No.	Name of river	Length (km) Catchment area (km²)	Highest peak (m) Lowest point (m)	Land Use (%) 1997
1	**Pahang River** (main river)	440 27,000	Mt. Tahan (2,187 m)	F (73.2), U (0.1), R (10), P (2.2), L(10), OP (4), A (0.5)
2	**Jelai River** (Tributary)	156 7,320	Mt. Siku (1,916 m)	F (85), OP (2), R(4), L (9)
3	**Tembeling River** (Tributary)	153 5,050	Mt. Besar (790 m)	F (66), OP(12), R (13), L(9)

Source: Catalogue of river UNESCO

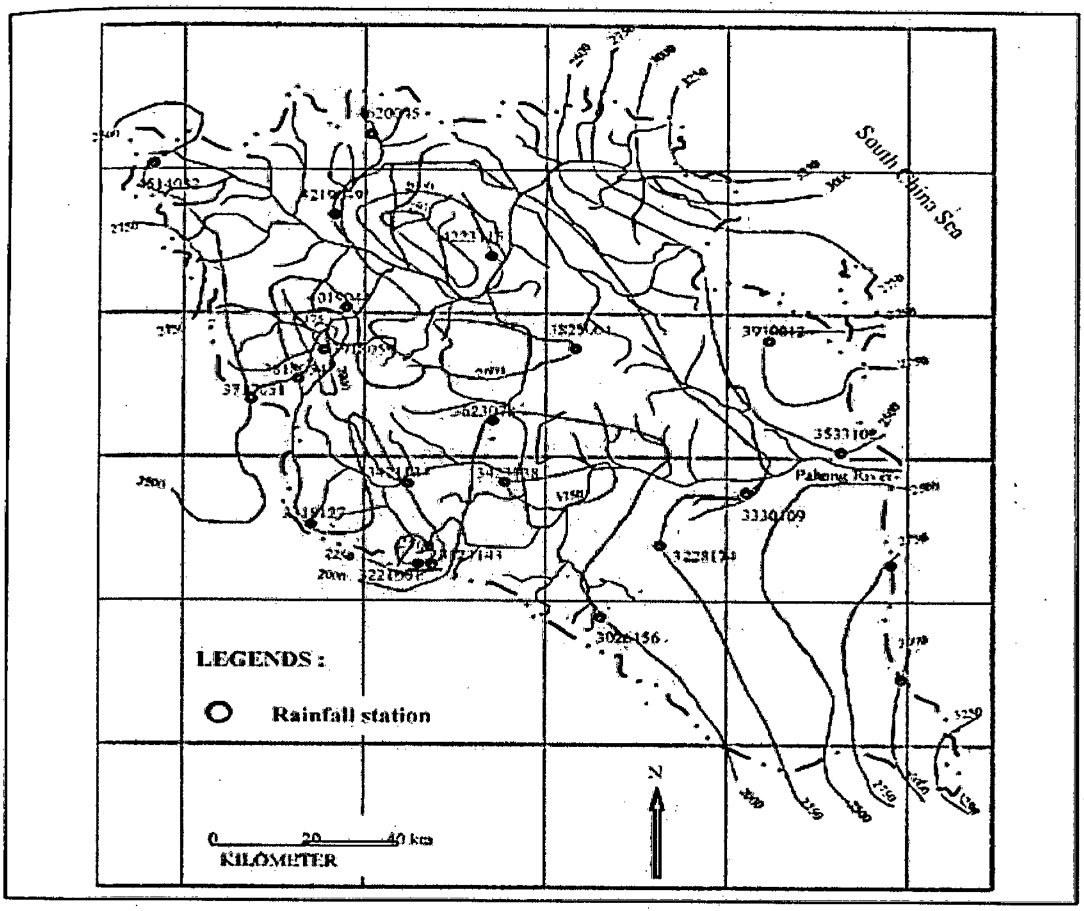

Figure 1.3: Annual Isohyetal Map and Observation Stations

(Source: Catalogue of river UNESCO)

1.4.2 Rainfall Data Analysis

Rainfall is the discharge of water, in liquid or solid state, out of the atmosphere, generally upon a land or water surface of subsurface. The term "precipitation" is also commonly used to designate the quantity of water that is precipitated. (Meinzer, 1923, p.15)

The Spatial analysis of the **Rainfall** in the Pahang River basin has been performed using the monthly values of 5 years (2005-2010). The Tropical Rainfall Measuring Mission Multi-satellite Precipitation Analysis (TMPA) satellite-based monthly rainfall (3B43version 7) obtained from public domain were used.

1.4.3 Actual-Evapotranpiration Data

AET is the process by which water is changed from the liquid or the solid state into the vapour state. Monthly AET information was derived from series of Normalized Difference Vegetation Index (NDVI) bio-physical index using model introduced by Ali (2014).

1.5 THESIS STRUCTURE

This research consists of five chapters. Chapter one comprises the introduction section. It states the research background, problem statement, objectives of study and scope of study. For chapter two, describe the key term in- purpose of these research and comprises the literature review that related and suitable for these research. Chapter three explains the research methodology that used for planning research type of data collected and the method of data analysis to be employed. For chapter four present the result that obtained from the study area and year of study and discussed the result from analysis. Finally, chapter five comprises the conclusion from the overall chapter and relates some recommendation for future work on research field.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

A drought happens when a period of low rainfall leads to a shortage of water. It is starting when total rainfall is below average for several months. Drought resulted in reduced water supply. Through this study, the data required for water-yield results in the future of water study.

Water-yield is the avaibility of water resources for water runoff and soil water or ground water storage (Brauman et al., 2007). Water is the precipitation minus the evapotranspiration (Langbein and Kathleen, 1995). Water-yield is runoff from the drainage basin, including ground water outflow that appears in the stream and total outflow from all part of drainage basin including surface channel or subsurface. One of the most accurate measurements made in small catchment is streamflow or discharge. Streamflow is the integrated result of all meteorological and hydrologic process in the catchment.

According HyperDictionary (2009), water-yield is known as the run-off water from the whole of part of the basin (or region) either through the surface or sub surface aquifers in a given time period (eg, one year). However, runoff is combination of river discharge runoff measurements give good accuracy the quantity of water-yield is also a result of a combination of meteorological and hydrological processes in the basin. The purpose of water-yield is to better water management and water supply can meet the demands during drought and monsoon season events.

Although the system does not produce water basin ecology on its own, it can change the amount of water through the landscape of the basin (Brauman et al., 2007). Quantitative assessment of water and product information changes, the effects of climate change and human activities, can be done using a water balance analysis of the basin. Further, the assessment of water resources for s region, province and continent can be obtained (Sokolov and Chapman, 1974). Based on studies by previous researchers, the water balance analysis provides a good framework for study of hydrology of the area. The imbalance that exists, leading to the identification and description of hydrological process and measurement techniques are good. Ideally, each component (ie, rainfall, precipitation, AET, runoff and water storage changes) to balance water needs to be measured. When all components have been determined, the waste arising is the deviation of the water balance to zero. However, the measurement is limited to major components (ie, rainfall and AET), also can produce results adequate for most purpose of estimating water-yield, predicting the effects of changes in land cover and use the water-yield and climate change (Arnell, a992; Gleick, 1987 a,b).

From the results of water balance, various hydrological models can be derived. Hydrological model is a mathematical model to transform input elements such as rain water runoff or discharge of river runoff. It is a simple concept to model complex physical model. Rainfall-runoff model was used for a variety of uses, from water-yield watershed to estimate the impact on its characteristics as a result of changes in land use and cover, and climate change (Singh and Frevert, 2002). The model is calibrated in the watershed with a record of river runoff discharge. Then, the model was used to estimate water-yield and changes in the basin that has no running water discharge rate information. Two procedure often used, the first being the closest model of the basin, and second, a model of the basin that has similar characteristics are used as a reference to predict the changing landscape of the basin system that does not have the information.

Determination of water-yield information in the study, focusing on the use of satellite image data as a source of information both key components of the input (ie, rainfall) and output (ie, AET). For this study, the literature review is divided into three major parts. First, determination of the water-yield with the water balance analysis and the impact of changes in land cover and use. Second, the determination of the distribution of rainfall from satellite image data and third, the determination of actual evapotranspiration (AET) from the satellite image.

2.2 DETERMINATION OF WATER-YIELD AND WATER BALANCE ANALYSIS AND EFFECT OF FOREST COVER AND LAND USE CHANGE

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

2.2.1 Hydrological Cycle and Water Balance Analysis

Water balance is the accounting of water for a particular catchment, region or even for the earth as a whole. In the hydrological cycle, rainfall that reaches the soil surface (ie, drainage, rivers, lakes) will be surface water, or filtered into soil moisture or infiltrate into the groundwater storage. Further, is released into the atmosphere through evaporation (from the soil surface, lake, river, sea) and evapotranspiration from the plant. How rainfall is distributed to the hydrological components (ie, runoff, soil moisture, groundwater), depending on space and temporal variability of rainfall and surface characteristics (Figure 2.1)

Water balance is defined by the general equation of hydrology, which statement is the law of conservation of mass (law of conversation of mass) as used in the hydrologic cycle. The equation is (Skolov and Chapman, 1974);

$$\text{Inflow} = \text{Outflow} + \text{Storage changes} \qquad (2.1)$$

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

i. Water balance can assess the hydrological cycle of any sub system, in any area and any time interval.
ii. Balancing water can act as a check whether all the flow and storage components involved have been accounted for quantitatively.
iii. Water balance can calculate the unknown component in the water balance equation, when other components are known with good accuracy.
iv. Water balance model can be used to complete the process hydrology. This means it can be used to predict the effects of changes in the components of other components in a system or sub-system.

With the features outlined above, the water balance is a solution to a significant problem in the theory and practice of hydrology. Based on the analysis of the water balance approach, enabling quantitative assessment of water resources and water resource change