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TREND ANALYSIS OF RIVER FLOW IN LANGAT RIVER BASIN USING SWAT MODEL

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Abstract: The increase in population and the human activities in this basin area has led to many water shortage problems. This research was carried out to investigate the impacts of land-use changes and urbanization on water discharge in Langat River Basin using ArcGIS. It was applied using the Soil Water Assessment Tool (SWAT). This research aimed to identify how critical land-use changes and the increment of the population in Langat River Basin could impact the water discharge. The rainfall, humidity, solar, wind speed data from 2010 – 2016 were used for modelling purposes. The results obtained from calibrated results were satisfactory, with the value of the coefficient of determination of 0.63 and the value of Nash-Sutcliffe Efficiency (NSE) of 0.69. The precipitation and river flow pattern observed shows decreasing in the river flow from May to September 2016 and increased in November to December 2016. It can be observed that the river flow decreased due to some factors, and this may be a concerning issue as Langat River Basin is used to supply water to people in Klang Valley. This paper has proven that the GIS technology and Arc SWAT model can simulate the streamflow in Langat River Basin and can be further demonstrated to other basins. The model also can be used for further analysis and for in the future.

Keywords: Calibrated; Population; Streamflow; Urbanization; River flow.

1. Introduction

In this era, many basins are polluted because of population increment and high usage of natural resources in developing the world's economy. Land and water are two essential elements daily. Two-thirds of the earth's surface consists of water, and 75% of the human's body is covered by water. Water is much needed by the land, just as much as the human body. For land, water will transport and dissolve nutrients and organic matter while carrying away all waste material. On the other hand, water will regulate the body's fluids, tissues, cells, lymph, and blood activities.

Compared to those days, this contemporary developed technological society has been taking advantage of our natural resources. Our natural heritage, such as rivers, oceans, and seas, has been mistreated, exploited, and contaminated. This act resulting in many kinds of pollutions and problems occurred to the environment.

As for land, in the past, society treated their land in so many ways. Some of them look at it as their dignity, as their shelter where they live and grow. While for some other people, the land is an area where they could produce grains, fruits, and other kinds of food as their livestock. Unfortunately, modern society is recklessly treating land and simultaneously affecting the environment. The growth of population and the increasing numbers of human needs causing harm to the ecosystem (Irimia & Gottschling, 2016).

Humans have had a shaky connection with the land throughout history. Humans used to land with modest adaptations for shelter, food gathering, and shielding purposes back then. Land use did not result in significant changes in the terrain until 10,000 years ago. Large-scale clearance for each town and cultivation came with domestication. Structures are being created to accommodate both reasonable and unreasonable activities as the population grows. The change in total runoff and streamflow, peak flow characteristics, and a reduction in water quality will occur directly or indirectly as the number of urban population density and built-up regions increases (Ali et al., 2012; Butler, 2013; Liu et al., 2017).

2. Materials and Methods

2.1. Study Area

The area of interest for this study is Langat River Basin, Selangor, Malaysia, with a total catchment area of 2271 km^2. Langat River Basin is the most urbanized river basin in Malaysia in the southern part of Klang Valley. Three significant tributaries drain this catchment: Langat River, Semenyih River and Labu River. Langat River flows approximately 182 km from Titiwangsa Range (Banjaran Titiwangsa) at the Northeast of Hulu Langat, and it drains westward to the Straits of Malacca. Two reservoirs are involved in this study area, which Langat dam and Semenyih dam. At this present time, eight water treatment plants are operating in Langat Basin.

2.2. Input Data and Model Setup

The data from 2010 – 2016 were used for modelling purposes. The model was calibrated using Calibration and Uncertainty Programs (SWAT CUP) using the Sequential Uncertainty Fitting Version 2 (SUFI 2) technique. The meteorological data such as rainfall, humidity, solar, and wind on a daily time step from the Year 2010 to 2011 were used as a model warm-up; data from the Year 2012 to 2014 were used for calibration, and on the other hand, data from the Year 2015 to 2016 were used for model validation. Hydrological data such as water quality and rainfall data were obtained from the Department of Irrigation and Drainage (DID), which contained six rainfall stations in total. Meteorological data, topographic maps, and soil and land use maps were obtained from Malaysian Meteorological Services, Survey and Mapping Department, and Agricultural Department of Malaysia (Buckner, 1978; Ali et al., 2014).

2.3. Building the Model

Digital Elevation Model (DEM) map, with 30m x 30m resolution, was the first input data to develop the model in the GIS interface. Once the model was generated, the process of watershed delineation was carried out. The other input data, such as precipitation, humidity gauge, and temperature, were inserted inside GIS by implementing the coordinates in terms of X and Y. The direction of the river flow is built from the upper stream of the river. The whole network of the Langat catchment was built as the whole process continued. **Figure 1** below shows the watershed delineation of the Langat River basin.

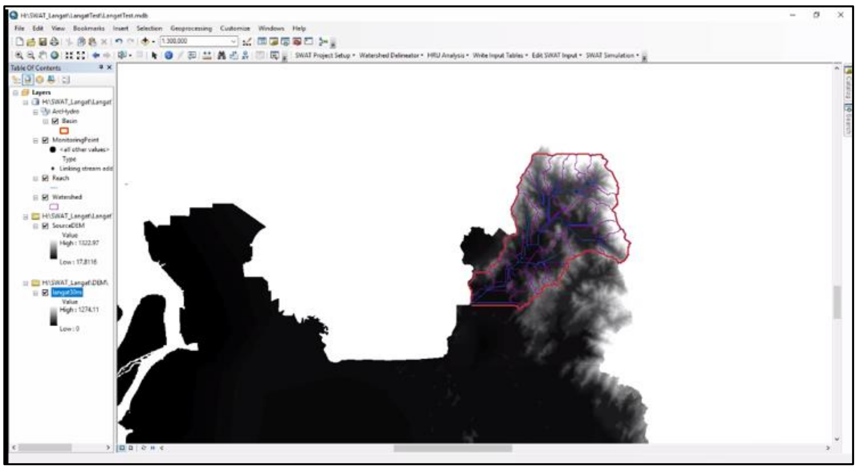

Figure 1. Watershed delineation of Langat River basin

The SWAT model was continued by inputting all the data and following the procedures of hydrological modelling as shown in the flowchart of hydrological modelling in Langat River in **Figure 2** below.

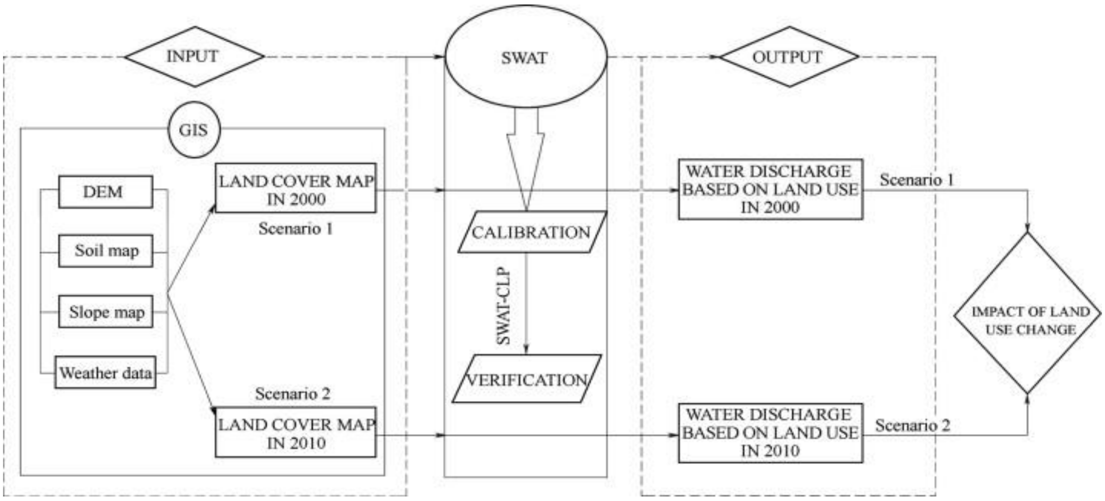

Figure 2. Flowchart of hydrological modelling in Langat River

2.4. Model Calibration and Validation

Calibration was done based on SWAT-Cup by using project type SUFI2 (Sequential Uncertainty Fitting), where data are calibrated and validated. The usage of the SUFI-2 program was for a combined analysis of optimization and uncertainty. SUFI-2 is a multisite and semiautomated global search procedure.

The objective function has been formulated as the Nash-Sutcliff Efficiency (NSE) between measured and simulated discharges. The data used for this calibration process was observed and simulated monthly data for 2012, 2013, 2014, 2015, and 2016. Calibration is the process of adjustment of the model parameters to replicate physical flow on-site. The parameters can be acceptable with the standard range between observation and simulation. **Table 1** shows the adjusted parameters in the calibration process as well as the values. A different set of data from the year 2015 to 2016 was used for the validation process. The parameters considered are SCS runoff curve number, subsurface water response (alpha baseflow, groundwater delays) and threshold depth of water (Amini et al., 2009; Yang et al., 2011; Khalid et al., 2015).

Table 1. Parameters for calibrated SWAT model

No.	Function in SWAT Cup	Calibrated Value	Min. Value	Max. Value
1	Subsurface water response (GW_DELAY)	53.000	0	500
2	Threshold depth of water (GWQMN)	2.000	0	5000
3	Subsurface water response (RCHRG_DP)	1.000	0	1
4	Initial SCS runoff curve number (CN2)	0.058	0	98
5	Subsurface water response (ALPHA_BF)	0.235	0	1

2.5. SWAT Overview

The Soil and Water Assessment Tool (SWAT) is a model that simulates the effects of land use, land management, and climate on water quantity and quality. The U.S Department of Agriculture, Agricultural Research Service (USDA, ARS) was the researcher who developed SWAT in the mid- the 1990s. A lot of reviews and expansions the model has undergone since it was established. As a result, over 1000 peer-reviewed journal articles describing the applications and enhancements of the model has been well-documented in a user manual (Graham Sustainability Institute, 2016). This model uses mathematical equations to impersonate watershed processes such as hydrology, soil erosion, and the cycle of nutrients on the land. Moreover, the small spatial units are the hydrological response units (HRUs), which contain soil type, land use, and slopes (Perez-Valdivia et al., 2017).

3. Results & Discussion

For this research, the calibration results were considered satisfactory. The coefficient of determination, which R^2 represents, was obtained with the value of 0.63, and this result was achieved based on the year 2012 – 2014 calibration result. That coefficient of determination is considered satisfactory based on the standard ranges between 0 – 1. Therefore, the higher the value of the coefficient of determination, the more accurate the model. The comparison between the simulated result and the observed result of the calibration process for 2012 - 2014 has an acceptable value of NSE value of 0.69. The result can be considered the best-simulated result, based on the NSE performance rating. **Table 2** below shows the results obtained for calibration and validation.

Table 2. Efficiency of SWAT model

Efficiency of SWAT model for Flow Out (cms)	**Calibration**	**Validation**
Coefficient of Determination (R^2)	0.63	0.61
Nash-Sutcliffe Efficiency (NSE)	0.69	0.56

According to the results **Figures 3, 4, 5, and 6**, the calibration values were higher than the validation values, but both are acceptable and satisfactory. Other than that, the trends of observed and simulated values were also considered good with the streamflow (flow out) simulated and observed matching to each other.

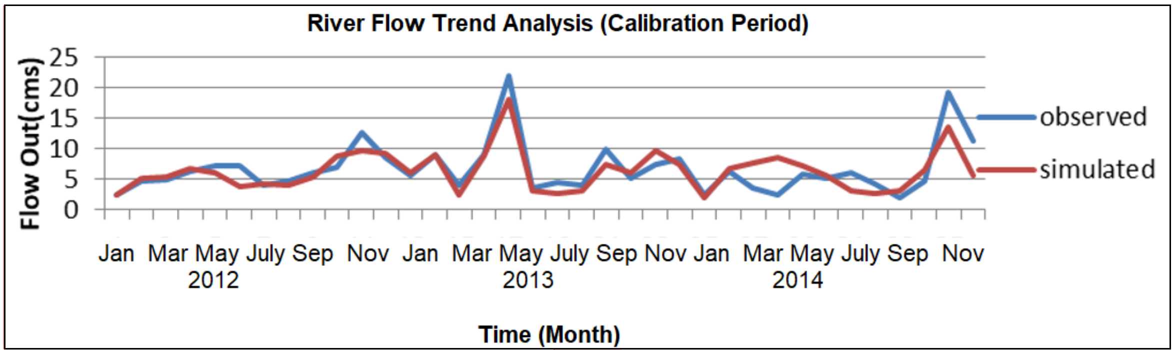

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Figure 3. River flow trend analysis for the calibration period

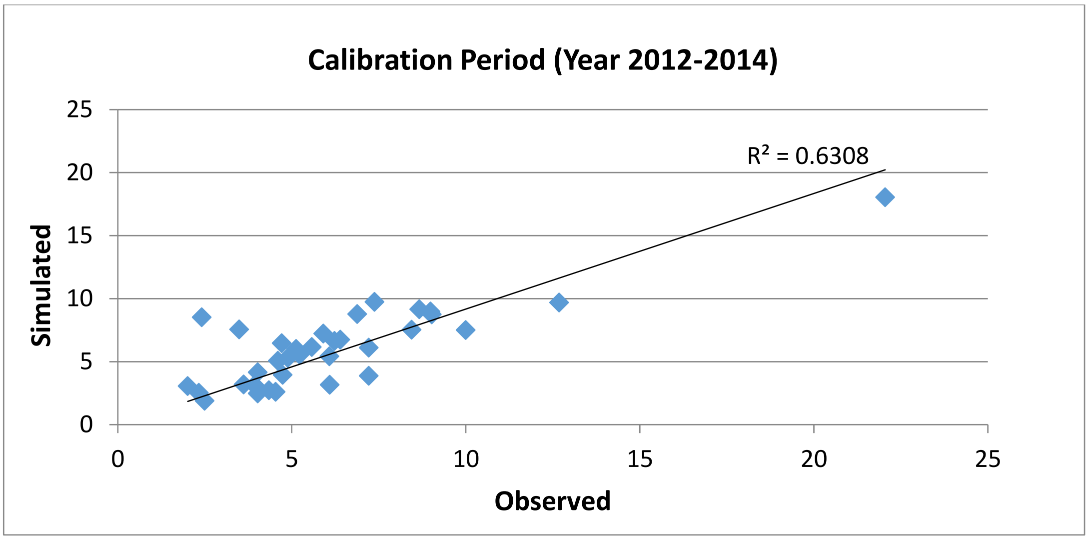

Figure 4. Coefficient of determination for the calibration period

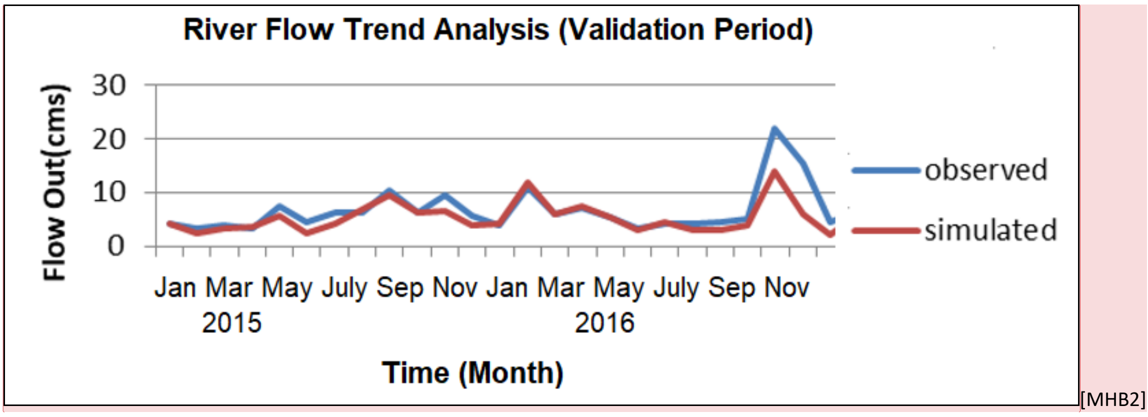

Figure 5. River flow trend analysis for the validation period

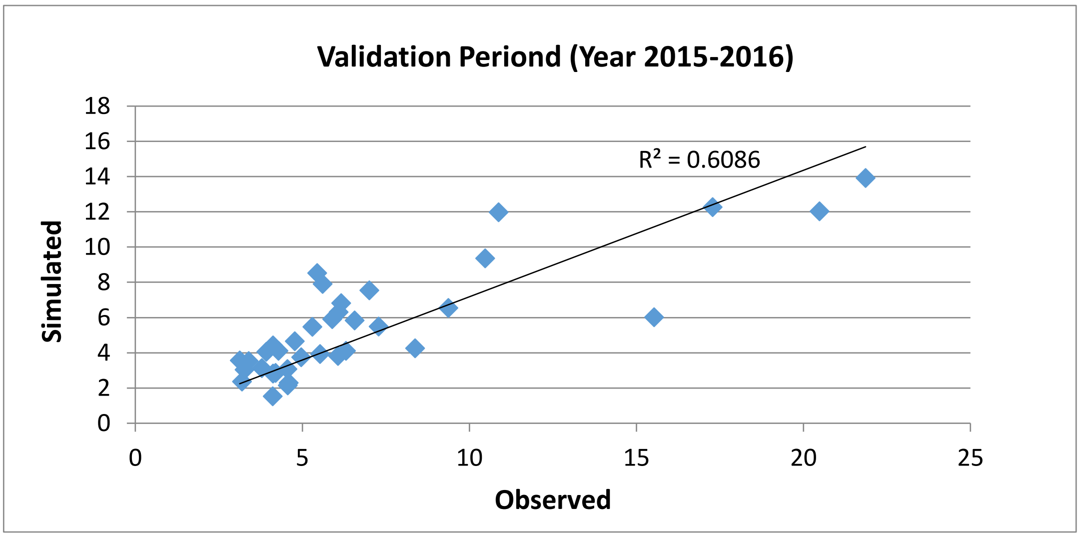

Figure 6. Coefficient of determination for the validation period

Figure 7 shows a precipitation comparison for the year 2012 to 2016. It can be understood from the results that the year 2016 had an intense amount of rainfall compared to 2012. From the beginning of the year, which is January, until December, the monthly rainfall data of 2016 were higher than 2012 in every single month. Due to the amount of increasing precipitation in 2016, it can be reported that surface runoff is due to an infiltration factor, where some of the rainfall amounts infiltrate into the ground or the absorption of water by the soil in that month. This has resulted in the increasing river flow, as shown in **Figure 8**. It can be observed that January, April, May, June, July, August, September, and October of 2012 show higher river flow than 2016. This shows that as the year increased, the population in the Langat River basin increased, at the same time affecting the land use as well as the water discharge in the river basin.

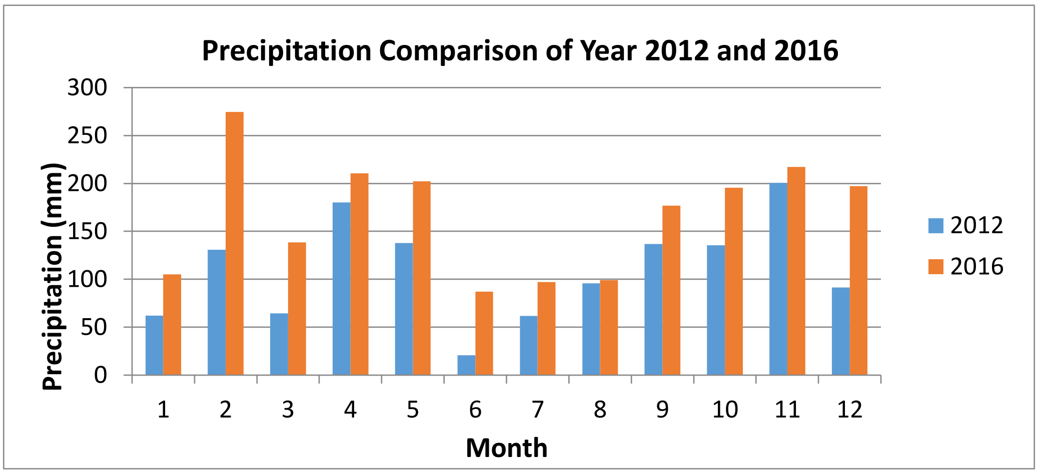

Figure 7. Precipitation comparison for the year 2012 to 2016

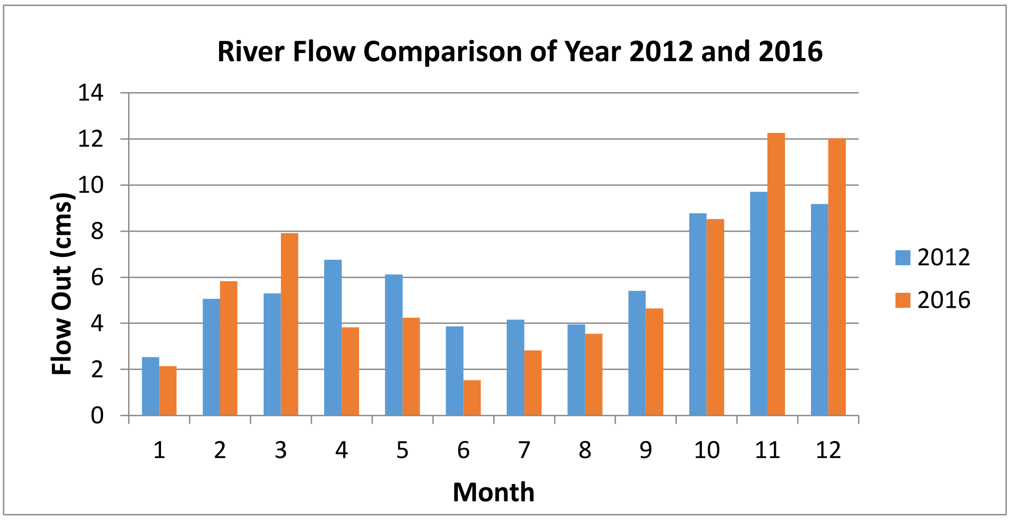

Figure 8. River comparison for the year 2012 to 2016

This paper has discussed the changes in precipitation values and river flow in the Langat River Basin for a five-year duration from 2012 to 2016. The river shows some significant change within these five years. However, the increasing amount of precipitation and river flow should not be neglected; this could be one of the concern matters, where it kept increasing as the year increased. Langat River Basin could experience a severe flooding problem if no immediate action is considered on this matter. It can also be observed that the amount of river flow throughout those five years did not have intense changes, but most of the months that had a high amount of water discharge were in 2012. The analysis shows that in 2016, the month of January, April, May, June, July, August, September, and October experienced a decrease in the amount of rainfall. Therefore, as the year increased, the amount of water discharge decreased due to some factors, and this may be a concerning issue as Langat River Basin is used to supply water to people in Klang Valley. Besides rainfall characteristics such as intensity and distribution, the soil type could also affect runoff and river flow. The amount of infiltration depends on the porosity of the soil, which affects the water to flow into a more profound layer of soil.

4. Conclusion

Using the precipitation data obtained from the Department of Irrigation and Drainage (DID) from 2012 until 2016, it was used to run and simulate using GIS software and the SWAT model. The model was successfully run, and many other kinds of data managed to be obtained, such as surface runoff, flow out, soil map, land use map, and HRU results of Langat River Basin from 2012 until 2016.

The model efficiency obtained for Langat River Basin were evaluated by the value of the coefficient of determination, R^2 = 0.63 and Nash-Sutcliffe Efficiency (NSE) of 0.61 for calibration, while on the other hand, for validation, the R^2 and NSE values obtained were 0.69 and 0.56 respectively. This model is satisfactory according to the performance ratings. Thus, the hydrological model for Langat River Basin has successfully been developed, calibrated, and validated. The precipitation and river flow pattern observed shows decreasing in the river flow from May to September 2016 and increased in November to December 2016. It can be observed that the river flow decreased due to some factors, and this may be a concerning issue as Langat River Basin is used to supply water to people in Klang Valley.

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