Correlation between runoff volume and land use changes using SCS-CN method for Sungai Gombak catchment

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Abstract. This research focuses on river modeling using the input precipitation and land use system Soil Conservation Service Curve Number (SCS-CN) using InfoWorks RS (IWRS) and Geographical Information System (GIS). The purpose of this study is to measure the volume of runoff based on the year selected for the Sungai Gombak model with changes in land use base. Sungai Gombak is part of the upper basin of the Sungai Klang. The Sungai Klang basin area has undergone significant urbanization, especially upstream in Sungai Batu, Sungai Gombak and Sungai Klang. This urbanization is the most significant changes in land use happening within the basin of the lake. For the Sungai Gombak catchment, the transformation of the undeveloped area that lead to Sungai Gombak changing the amount of runoff. Six rainfall stations were selected to model the river and then the average catchment rainfall for each catchment was interpolated using Thiessen method from the available rainfall station. Three rainfall events were chosen based on the flood history reported by the Department of Irrigation and Drainage (DID) in the Sungai Gombak. The results indicate that the CN value rises from year to year due to changes in landscape patterns that indirectly influence ecological processes and decrease the stream flow time concentration.

1. Introduction

These days, the urbanization is exceptionally imperative for a creating nation particularly in Malaysia. Arrive utilize changes and urbanization have changed undeveloped of urban regions, since these zones have experienced critical development in later decades. Landscape pattern is characterized as spatial courses of action of different scene components in several sizes and shapes which, impacted by normal variables and human exercises. The alter in landscape pattern configuration might by implication affect environmental forms within the landscape; in this way, the issues related to landscape pattern alter have initiated the consideration of the universal social orders approximately the land use change, urbanization and ecological structure [1].

The Sungai Klang basin area has undergone major urbanization, particularly upstream in Sungai Batu, Sungai Gombak, and Sungai Klang. This urbanization is the most significant changes in land use happening within the basin of the river. For the Sungai Gombak catchment, the transformation of the undeveloped region will lead to Sungai Gombak changing the amount of runoff. As regions are changed to urban used, the characteristic woodland is demolished, land inclines are adjusted and ranges are cleared over due to social improvement action [4]. Other than, volume of surface runoff and the rate of stream increment amid the advancement stage. Previously, runoff was discharged gradually into the stream, but presently fast improvement causes water to stream rapidly over the surface and into the streams. The expanded release amid urbanization forms will lead to surge inclined regions.
The SCS-CN method is utilized to foresee coordinate runoff from precipitation to explore the relationship between runoff volumes and land use. The objective of this study is to assess the relationship between runoff volume and land use utilizing the Soil Conservation Service Curve Number (SCS-CN) using InfoWorks RS (IWRS) and topographical data framework.

2. Methodology

2.1. Study area
Sungai Gombak is primarily located within the Selangor Gombak site and its lower zone is situated within the Kuala Lumpur capital of Malaysia. The stream has a few confluences within the middle of Kuala Lumpur with other streams like Sungai Batu, Sungai Untut, and Sungai Klang upstream. The catchment zone of Sungai Gombak is 116 km² and the length of the waterway is 34.6 km. Figure 1 shows outline of Sungai Gombak catchment region. The catchment area inside which the stream passes through, has grown quite quickly since early 1970s and is anticipated to continue developing within the future. The topography of the watershed area is made up of sloping hills. Sungai Gombak watershed is within the upper portion of Klang waterway basin. Approximately 60% of the catchment is saturated mountains that rise to a height of 1220 m. The Sungai Gombak drains a wide elongated river that runs slightly west of south from the steep sloping main mountains down through slightly sloping foothills to the alluvial plain near Kuala Lumpur in the north [5]. The tributaries of Sungai Gombak are Sungai Keroh, Sungai Pusu, Sungai Rumpit, Sungai Salak, Sungai Semampus and Sungai Blongkong.

2.2. Data collection
Data collection involves from different departments and sources. Table 1 displays the study's data types and origin.

![Figure 1. Sungai Gombak catchment area](image)

**Table 1. Types of data and source**

| No | Type of data          | Source                          | Format |
|----|-----------------------|---------------------------------|--------|
| 1  | River cross section   | Department of Irrigation and Drainage (DID) | Digital |
| 2  | Contour and river layer | Department of Irrigation and Drainage (DID) | Digital |
| 3  | Map of river alignments | Department of Irrigation and Drainage (DID) | Digital |
| 4  | Satellite Image       | MECRAS                          | Digital |
| 5  | Land Use              | Department of Agricultural (DOA) | Digital |
| 6  | Soil Map              | Department of Agricultural (DOA) | Digital |
2.3. Rain gauge station

The flow had been demonstrated by six precipitation stations and the usual catchment rainfall for each catchment was applied from the accessible precipitation station using Thiessen strategy as shown in Figure 2. Three occasions of precipitation were selected by Department Irrigation and Drainage (DID) based on the surge history within the Sungai Gombak record. Therefore, on 21st December 1993, 10th June 2003 and 3rd June 2007, the three flood incidents were applied. In order to determine the curve number (CN), it is necessary to identify the types of land use activities around Sungai Gombak using information on land use in the years 1993, 2003 and 2007. The manual runoff volume calculations are compared with the three flood events simulation. The analysis was done by comparing simulation and observation runoff hydrograph.

![Figure 2. Rainfall station in the catchment area of Sungai Gombak](image)

2.4. SCN-CN Method

While relatively well planned and controlled, rapid industrialization has placed increased pressure on urban areas, especially in the Sungai Gombak catchment. This research focuses on the relationship between the form of land use has had a significant impact on the nature of the amount of runoff correlated with hydrological characteristics. For this analysis, the SCS-CN (Soil Conversation Service Curve Number) was applied to measure the rainfall-runoff associated with land use [6]. The equation of the CN is shown below:

\[
CN = \frac{CN_1 A_1 + CN_2 A_2 + \ldots}{AREA_{TOTAL}}
\]  

CN values differ in the range of \(1 \leq CN \gg 100\). This guideline for the CN value is considering the principles to be observed in deciding the CN value. The CN SCS runoff is a numerical river land use indicator. Hydrological soil group data, hydrological condition, treatment or practices and land use are used for the creation of a basin CN and the following catchment property that will produce runoff [7,8].

2.4.1. Hydrologic soil type. Based on their minimum infiltration rate, which is obtained for a bare soil after prolonged wetting, soils are classified into four hydrological groups. Table 2 shows a description of these groups.
Table 2. Hydrological type of soil [6]

| Soil type | Description                                                                                                                          | Infiltration rate (mm/hr) |
|-----------|----------------------------------------------------------------------------------------------------------------------------------------|--------------------------|
| A         | Lowest runoff potential. Includes deep sands with very little silt and clays, also deep, rapidly permeable loess.                          | 8 - 12                   |
| B         | Moderately low runoff potential. Mostly sandy soils less deep than A, and less deep or less aggregated than A, but the group as a whole has above average infiltration thorough wetting. | 4 – 8                    |
| C         | Moderately high runoff potential. Comprises shallow soils and soils containing considerable clay and colloids, though less than those of group D. The group has below-average infiltration after pre-saturation. | 1 – 4                    |
| D         | Highest runoff potential. Includes mostly clays of high swelling present, but the group also includes some shallow soils with nearly impermeable sub-horizons near the surface. | 0 - 1                    |

2.4.2. Land use. Land usage applies to a specific piece of land associated with manmade activities. The increase in population and human activities increases the demand for rural, woodland, pasture, residential and industrial land use on the limited land and soil resources. For proper planning, management and regularization of the use of these resources, data on the frequency and nature of changes in land asset use is important. Table 3 indicates the CN value based on the Sungai Gombak Basin activities.

Table 3. CN value depending on the operation [6]

| Activity                        | CN |
|---------------------------------|----|
| Forest land                     | 50 |
| Forest wetland                  | 50 |
| Agricultural area               | 60 |
| Electrical supply               | 80 |
| Transport facilities            | 80 |
| Sport and recreation facilities | 80 |
| Offices                         | 80 |
| Railways                        | 80 |
| Cemetery                        | 80 |
| Village houses                  | 80 |
| Cleared land                    | 80 |
| Field land                      | 80 |
| Idle land                       | 80 |
| Industrial                      | 90 |
| Road                            | 90 |
| Religious area                  | 90 |
| Terrace houses                  | 90 |
| Water bodies                    | 100|
| Sewerage                        | 100|
| Irrigation and drainage         | 100|

2.4.3. Type of soil surface. Gombak is part of the urban area of Kuala Lumpur, and tin mining areas are mainly defined as disturbed land. The forest area north of Gombak is graded as steep, but this is likely to mostly belong to the granite-forming Renggam-series, though probably shallower. The Renggam sequence is located in a belt at the center of the basin from the inside of the steep north land and down into the hilly area. Topsoil's textural category is rough sandy clay loam. Figure 3 displays the Gombak catchment soil type.
Certain types of soil found around disturbed soil include Serdang series associations with series Kedah, Durian, and Munchong. Serdang is made of sandy loam to sandy clay loam, with the fraction of sand considerably finer than that found in the Renggam sequence. Serdang associations are also found in the middle of the catchment to the northwest of the granite belt. It will suggest that it is possible to identify the Gombak as soil group Group B. Once the soil group has been selected, it will look at the water in the soil's infiltration rate. Minimum rates of infiltration as shown in Table 4. The soil class has been identified as Group B means that this watershed has an infiltration rate of 3.8 to 7.5 mm/hr.

### Table 4. The required level of soil infiltration [6]

| Soil type | Minimum Infiltration Rate (mm/hr) |
|-----------|-----------------------------------|
| A         | 7.5 to 11.5                       |
| B         | 3.8 to 7.5                        |
| C         | 1.3 to 3.8                        |
| D         | 0 to 1.3                          |

### 3. Results and discussions

The land use map is used to classify the catchment information in the process of determining CN values. Description of land use categories such as virgin forest, cleared area, town area or urbanized area and so on were defined in the land use map. Every class has its own values for CN. The data is used in the 1993, 2003 and 2007 combined data analysis. Figure 4 shows the map of land use abstracted by using GIS from calculation.
The Sungai Gombak catchment was divided by land use activity categories based on the land use map. The upper part of the sub-catchment was covered with the virgin forest area in 1993. In the middle of the sub-collection, the factory industries and educational institutions such as the International Islamic University of Malaysia were developed. With a small high-rise tower and small properties, the lower part of the sub-catchment protects. The technology has grown dramatically in the 10 years later. In 1990, the population of the Gombak catchment was approximately 200,000, with a growth rate of 7% per year. As a result, the growth rate will increase year after year. The population increase will be impacted by the CN's rise, as shown by the CN's shifts from 1993 to 2003 and up to 2007. Figure 5 shows CN's average.

![Figure 5. The CN average.](image)

### 3.1. Comparison of manual calculations with observation data

This reveals some of the gap between analysis and measurement from the outcome of the manual calculations. The sum of the manual calculations is shown in Table 5. From the event on 21st December 1993 and 3rd June 2007, a small percentage difference resulted. The percentage difference between the results of the manual estimation and the measurement data is 7.6% and 7.9%. The results of the stream flow for the event on 10 June 2003 were 146.2 m³/s compared to 149.25 m³/s for the measurement and the difference is about 2.0%.

| Event                  | Observation (m³/s) | Manual Calculation (m³/s) | Percentage Difference |
|------------------------|-------------------|---------------------------|-----------------------|
| 21st December 1993    | 56.4              | 60.7                      | 7.6%                  |
| 10th June 2003        | 149.25            | 146.2                     | 2.0%                  |
| 3rd June 2007         | 104.99            | 96.65                     | 7.9%                  |

### 3.2. Analysis of the runoff with the changes of CN

#### 3.2.1. Event on 21st December 1993

The simulated peak is 52.9 m³/s whereas the observed level peak is 56.4 m³/s which is the difference about 3.5 m³/s. The calibration started from 1.00 pm to 11.45 pm and the peak flow is at 10.30 pm. During 1993, the average CN for this catchment is 67 and the time concentration taken is 1.34 hours to flow from the upper part of the watershed to the point value at Jalan Tun Razak, Kuala Lumpur, which is the stream flow station. Figure 6(a) shows a comparison of the stream flow in 1993 in Sungai Gombak at Jalan Tun Razak between observed and simulated.

#### 3.2.2. Event on 10th June 2003

The research starts with the 1993, which is the year 2003, 10 years later. Figure 6(b) shows a comparison of the stream flow in 2003 in Sungai Gombak at Jalan Tun Razak between observed and simulated. The model predicts a peak stream flow against an observed
peak stream flow of 149.25 m$^3$/s is 148.9 m$^3$/s for this event. The difference between observed and simulated is slightly small, 0.35 m$^3$/s and the hydrograph pattern shows in the model is good shape to predict stream flow at the point of interest. The value of CN is 78, which means that from 1993 to 2003, the CN will increase dramatically from 67. Time concentration also drops from 1.34 hours to 0.97 hours in the meantime.

3.2.3. Event on 3rd June 2007. The peak stream flow at Jalan Tun Razak in Sungai Gombak in 2007 is 104.99 m$^3$/s, while the simulated stream flow is 104.54 m$^3$/s as shown in Figure 6(c). The difference between simulated and observed performance, which is 0.45 m$^3$/s, is slightly small. The 86 CN used in the calibration design and, as a result, the form of the hydrograph looks very gentle and nice like the hydrograph of the observation runoff. The small concentration of time is taken, which at the point of interest is 0.78 hour to hit.

3.3. Comparison of InfoWorks simulation result with manual calculations of runoff volume
The runoff volume for the Sungai Gombak catchment was determined using two differential methods. The approach used the equation of variance, but with the small range, the output was exactly the same. It indicates the correlation result between the manual estimation and the simulation of InfoWorks on the three events by referring to Table 6. The manual calculation output shows a small difference with InfoWorks simulation. The range of variations is 2.7 to 8.3. The small range occurred because the lateral flow from the tributaries was not considered by the manual calculations.
Figure 6. Comparison of stream flow for year (a) 1993, (b) 2003 and (c) 2007 in Sg Gombak at Jalan Tun Razak.
Table 6. Manual calculations correlation with simulation of InfoWorks

| Event               | Manual Calculation (m³/s) | InfoWorks simulation (m³/s) | Difference |
|---------------------|---------------------------|-----------------------------|------------|
| 21st December 1993  | 60.7                      | 52.9                        | 7.8        |
| 10th June 2003      | 146.2                     | 148.9                       | 2.7        |
| 3rd June 2007       | 96.65                     | 104.99                      | 8.3        |

4. Conclusion
It can be concluded from the study that the CN value increases from year to year due to changes in land use activities and the time concentration of stream flow taken is short after land use change. The volume of runoff depends on that event's total rainfall, if the rainfall is high, the stream flow is also high at that time. All six stations are interpolated from the available rainfall station based on average catchment rainfall for each sub catchment. In addition, the results that have been obtained are with the observation data approximately.

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