Analysis of classification hydrologic soil group distribution based on infiltration rate of horton method in the upper Ciliwung watershed

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Abstract. Runoff coefficient or Curve Number (CN) is a parameter value needed to describe runoff in accordance with the intended land use. In determining CN values, it is necessary to take account the Hydrologic Soil Group. The Hydrologic Soil Group (HSG) consists of 4 groups, which are: A, B, C, and D. In order to classify the appropriate HSG, several methods can be used, namely: soil properties, soil maps, or minimum infiltration rates. In this research, an HSG classification distribution analysis will be carried out based on the infiltration rate obtained from actual conditions found during observation in the research site. This research was conducted in 13 locations situated in the Upper Ciliwung watershed. The division of 13 locations is based on the distribution map of the HSG according to the Geological Information Agency and also the map of the distribution of Upper Ciliwung sub-bases. In its classification, each HSG has a different infiltration rate value. In this study, an analysis of the distribution of HSG classification based on the infiltration rate was obtained from direct observation on the research site. The study was conducted using a double-ring infiltrometer. The data obtained from the study were then processed using parameter estimation and the Horton Method to obtain the Horton infiltration rate. When the infiltration rate value is known, the corresponding HSG can then be determined for the soil at that particular location. With Inverse Distance Weighted in ArcMap, a map of the spread of infiltration rate and classification of HSG will be obtained in the Upper Ciliwung watershed. The infiltration rate obtained in the Upper Ciliwung watershed ranges from 0.15-12.6 cm/hour. The distribution of HSG is also found in the Upper Ciliwung watershed, consisting of groups A, B, and C.

Keywords: Ciliwung Hulu, Double-ring Infiltrometer, Hydrologic Soil Group, Infiltration Rate of Horton Method

1. Introduction

Watershed is a land area that is bounded by mountain ridges which serves to store or store rainwater for further flow into the sea through the main river [1]. In Indonesia alone, there are 458 watersheds, some of which are in critical condition due to changes in land use [2]. One of the Watersheds that is experiencing a critical condition and a priority to be restored in accordance with the 2015-2019 Medium-Term Development Plan (RPJMN) is the Ciliwung River Basin [3]. Based on research conducted by Drs. Irfan B. Pramono, M.Sc, the Ciliwung River contributes to 24% of floods that occur in DKI Jakarta. While the Upper Ciliwung watershed, contributes to flooding by 8%. In analyzing a watershed, one of the parameters needed is the runoff coefficient or curve number. This
value describes the rainwater that becomes runoff or is infiltrated into the soil in accordance with the allotted land use. In determining the value of these parameters, it is necessary to consider the classification of soil types or the grouping of hydrological soils (Hydrologic Soil Group). The Hydrologic Soil Group consists of 4 groups namely A, B, C, and D. When the hydrological group types are different, then the Curve Number or Runoff Coefficient values will be different. However, the required Hydrologic Soil Group map is not available.

The classification of the distribution of the Hydrologic Soil Group in the Upper Ciliwung River Basin is divided into three groups namely, A, B, and D [4]. The classification of the distribution of the Hydrologic Soil Group is based on the soil map and the geological map of the Upper Ciliwung River Basin. In its classification, different Hydrologic Soil Groups have different infiltration rate values. So that by knowing the value of the infiltration rate at a location, the Hydrological Soil Group at that location will also be known.

2. Research Methodology

In this study, direct research was carried out at 13 locations to get primary data in the form of a decrease in water level (cumulative infiltration of the field) and environmental conditions at each research location in the Upper Ciliwung watershed. In addition, this study also uses secondary data that will help the data processing, namely the Upper Ciliwung watershed map, soil type maps, and daily rainfall data at the rain station that contributes to the Upper Ciliwung watershed. In this study, a double-ring infiltrometer is used to observe and measure the height of water entering the ground. This water level is used to calculate the infiltration rate using the Horton Method calculation. The results acquired from the observation is found as a form of decrease in water level (Δh) with respect to time (Δt). Measurements were first made to ensure that the water level that entered the ground was constant at a time interval. Furthermore, the data is processed into a graph showing the relationship between accumulation of decrease in water level and accumulation of time. The accumulation of the decrease in water level is in the form of the total incoming water, which is the sum of the height of the water level entering the ground. Accumulated infiltrated water is in the form of water flux, where to calculate the infiltration rate is done by calculating the slope of the curve or the first differentiation from the curve equation. By using the Horton infiltration calculation method, the accumulation of decrease in water level can be calculated with the following equation.

\[ F = f_0^1 f(t) \, dt = f_e t + \frac{(f_0-f_e)}{k} (1 - e^{-kt}) \]  

a. \( f_0 \): initial infiltration rate, is the infiltration rate calculated from the initial entry of water into the soil layer or infiltration rate at \( t = 0 \). The amount of the price of \( f_0 \) depends on the type of soil and surface layer. (mmh\(^{-1}\) atau cmh\(^{-1}\)).

b. \( f_e \): infiltration rate, is the final infiltration rate or when the infiltration rate is constant with time.

c. \( k \): decay time constant.

The parameters of the Horton infiltration model above are then calculated using the parameter estimation method using Ms. Excel. To get the equation of the horton infiltration model, the parameters are searched using the least square error. Parameter estimation is done by estimating the values of \( f_0 \), \( f_e \), and \( k \) until a Horton cumulative infiltration (F Horton) value approaches the field cumulative infiltration values (F field) thus producing the smallest square error value. This square error value is the square of the difference between the cumulative infiltration field value and the Horton cumulative infiltration value (theory). Square error can be written as follows.

\[ (F_{lap} - F_{teor})^2 \]  

In entering estimation figures to get the appropriate cumulative infiltration value, reference values are used based on previous research in accordance with the type of soil in the Upper Ciliwung Watershed and also adjusted to the existing field data. The infiltration rate values that have been obtained are then
mapped according to the points of observation. Based on the infiltration rate values obtained, these values are then identified with the infiltration value for each type of Hydrologic Soil Group so that the soil type group is known for each observation point in the Upper Ciliwung watershed. Then mapping of the infiltration rate and Hydrologic Soil Group in the Upper Ciliwung watershed area is done using the IDW (Inverse Distance Weighted) interpolation method in ArcMap GIS software. Where with this method the distribution of infiltration rates and Hydrologic Soil Group will be known throughout the Upper Ciliwung watershed.

3. Results and Discussion

3.1 Research Location

This research on infiltration rates to determine the distribution of the Hydrologic Soil Group classification in the Upper Ciliwung watershed was carried out at 13 different locations. The points of this research are based on the distribution map of the Hydrologic Soil Group according to the Geospatial Information Agency. Seen in Figure 1, the Hydrologic Soil Group in the Upper Ciliwung watershed according to the Geospatial Information Agency consists of groups A, B, and D. The points taken as research locations are taken to describe the rate of infiltration in the existing HSG zonation.

![Figure 1. Distribution of the Hydrologic Soil Group classification according to Badan Informasi Geospasial](Image)

The research location points are shown in Figure 2.
Figure 2. Research points on infiltration rates in the Upper Ciliwung Watershed

Figure 3. Map of sub-watershed division in the Upper Ciliwung watershed
Source: [5]
### Table 1. Research location coordinates

| No | Location          | x         | y         | z         | Sub-Watershed     |
|----|-------------------|-----------|-----------|-----------|-------------------|
| 1  | Ciesek            | 106.89783 | -6.64764  | 582.574   | Ciesek            |
| 2  | Indomaret         | 106.96954 | -6.69612  | 1050.053  | Upper Ciliwung    |
| 3  | Pondok Hijau Argan| 106.88835 | -6.64467  | 580.392   | Ciesek            |
| 4  | Warung Ibu Esih   | 106.98779 | -6.70599  | 1333.132  | Upper Ciliwung    |
| 5  | Puskesmas         | 106.85640 | -6.66130  | 479.314   | Ciseusepan        |
| 6  | Jl. Raya Sukaraja | 106.85429 | -6.64242  | 406.747   | Cibalok           |
| 7  | Gg Mabal          | 106.87698 | -6.66442  | 539.458   | Cisukabirus       |
| 8  | Bendungan Sukamahi| 106.87969 | -6.66942  | 609.099   | Cisukabirus       |
| 9  | Bendungan Ciawi   | 106.87903 | -6.65773  | 501.569   | Ciesek            |
| 10 | Wisma Galunggung  | 106.94186 | -6.68904  | 921.057   | Upper Ciliwung    |
| 11 | Villa HanGey      | 106.94507 | -6.69777  | 977.016   | Cisarua           |
| 12 | Wisma LPPA        | 106.92439 | -6.67309  | 777.833   | Cisarua           |
| 13 | JSI               | 106.90395 | -6.68799  | 712.238   | Cisukabirus       |

#### 3.2 AMC (Antecedent Moisture Conditions) Research Location

Classifying the AMC types can be done by looking at the amount of rain in the period of 5 days before the day of research or data collection in the field. To find out the amount of rain in each location, the author uses rain data from the Cilember Rain Station, Gadog, and Gunung Mas. The rain data used is the daily rainfall data obtained from BBWS Ciliwung Cisadane and also from rainfall observers of the locations of each rain station. Figure 4 shows the location of the rain station in the Upper Ciliwung watershed, which consists of the Gadog Rain Station, Cilember, and Gunung Mas.
Each research location is affected by a different rain station. So that the Thiessen Polygon method is used to find out the rain station that has an effect on each research location. The results of using the Thiessen Polygon method can be seen in Figure 5 below.

**Figure 4.** The location of the Rain Station in the Upper Ciliwung watershed

**Figure 5.** Map of the influence of rain stations on the Upper Ciliwung watershed based on Polygon Thiessen
Table 2. The location of the study and the rain station that affected it

| Rainfall Station | Affected Area (km²) | Location that Affected                      |
|------------------|---------------------|---------------------------------------------|
| Gadog            | 26 x 10⁵            | Jl. Raya Sukaraja                           |
|                  |                     | Pondok Hijau Argan                          |
|                  |                     | Puskesmas                                   |
|                  |                     | Bendungan Ciaawi                            |
|                  |                     | Gg Mabal                                    |
|                  |                     | Bendungan Sukamahi                          |
| Cilember         | 53 x 10⁵            | Ciesek                                      |
|                  |                     | Wisma LPPA                                  |
|                  |                     | JSI                                         |
| Gn. Mas          | 75 x 10⁵            | Wisma Galunggung                            |
|                  |                     | Villa HanGey                                |
|                  |                     | Indomaret                                   |
|                  |                     | Warung Ibu Esih                             |

From the distribution of the influence of the rain station, it is seen the amount of rain 5 days before doing research at the rain station that affects each location of the research point. This is to determine the AMC conditions at each research location according to the standards in table 2. The amount of rain during the 5 days before the study is conducted and the AMC conditions for each research location can be seen in Table 5 below.

Table 3. The amount of rain at each research location and AMC classification

| Location          | Rainfall Station | Research Date | Season | Total Rainfall | AMC |
|-------------------|------------------|---------------|--------|----------------|-----|
| Jl. Raya Sukaraja | Gadog            | 21 Februari 2019 | Wet    | 46             | II  |
| Pondok Hijau Argan|                 | 12 Juli 2018   | Dry    | 0              | I   |
| Puskesmas         |                 | 21 Februari 2019 | Wet    | 46             | II  |
| Bendungan Ciaawi  |                 | 22 Februari 2019 | Wet    | 47             | II  |
| Gg Mabal          |                 | 21 Februari 2019 | Wet    | 46             | II  |
| Bendungan Sukamahi|                 | 22 Februari 2019 | Wet    | 47             | II  |
| Ciesek            | Cilember         | 23 Maret 2018  | Wet    | 21.2           | I   |
| Wisma LPPA        |                 | 13 Juni 2019   | Dry    | 2              | I   |
| JSI               |                 | 13 Juni 2019   | Dry    | 2              | I   |
| Wisma Galunggung  | Gn. Mas          | 13 Juni 2019   | Dry    | 0              | I   |
| Villa HanGey      |                 | 13 Juni 2019   | Dry    | 0              | I   |
| Indomaret         |                 | 23 Maret 2018  | Wet    | 74             | III |
| Warung Ibu Esih   |                 | 12 Juli 2018   | Dry    | 0              | I   |

3.3 Infiltration rate of the Horton Method

Primary data in the form of water level that has been observed with a double ring infiltrometer is then processed to obtain the value of the infiltration rate at each point of the observation location. Processing of this infiltration rate using the Horton Method is assisted by the Ms. program. Excel is as
Table 4. Parameters of Horton Infiltration Equation and HSG Classification at Research Sites

| No | Location          | HSG (BIG) | $f_d$ (cm/jam) | $f_c$ (cm/jam) | k (/jam) | HSG (Research) |
|----|-------------------|-----------|----------------|----------------|----------|----------------|
| 1  | Ciesek            | B         | 2.5            | 0.65           | 3.7      | B              |
| 2  | Indomaret         | B         | 24             | 0.62           | 1.23     | B              |
| 3  | Pondok Hijau Argan | B       | 49.5           | 12.6           | 1        | A              |
| 4  | Warung Ibu Esih   | D         | 7.234          | 2.81           | 1.11     | A              |
| 5  | Puskesmas         | B         | 15.4           | 2.7            | 0.76     | A              |
| 6  | Jl. Raya Sukaraja | B         | 62             | 8.64           | 8.9      | A              |
| 7  | Gg Mabal          | B         | 23.9           | 11             | 5.76     | A              |
| 8  | Bendungan Sukamahi| B         | 3.5            | 0.75           | 9.5      | B              |
| 9  | Bendungan Ciawi   | B         | 12.5           | 0.15           | 12.37    | C              |
| 10 | Wisma Galunggung  | A         | 20.02          | 0.89           | 0.4      | A              |
| 11 | Villa HanGey      | A         | 31             | 2.55           | 0.4      | A              |
| 12 | Wisma LPPA        | A         | 1.5            | 1.2            | 1.48     | A              |
| 13 | JSI               | B         | 19.8           | 0.705          | 1        | B              |
Table 4 shows the differences in the HSG group from infiltration rates and the HSG group based on the Geospatial Information Agency. According to the authors, there are no wrong results because the methods used in the HSG grouping are different. Further information is needed related to the method or parameters used by the Geospatial Information Agency in this HSG grouping. In addition, it would be better in the HSG grouping to use or pay attention to several aspects and parameters at once, such as soil texture, organic matter, water content, porosity, and soil particle density so that the results of HSG grouping will be more accurate. In addition, to acquire a more accurate infiltration rate, more than 1 sample is needed at each point and should be carried out in different seasons. This will also better reflect the actual conditions of the soil. From the results that have been obtained related to the infiltration rate values at each study location, the distribution map can be made in the Upper Ciliwung watershed area using the help of ArcMap with the IDW (Inverse Distance Weighted) method.

![Figure 6](image)

**Figure 6.** Map of the Distribution of Infiltration Rate in the Upper Ciliwung Watershed

Figure 6 illustrates the distribution of infiltration rate values in the Upper Ciliwung watershed, where according to the legend, purple indicates the highest infiltration rate, while red is the lowest infiltration rate. From the infiltration rate values obtained, a distribution map of the Hydrologic Soil Group can also be made in the Upper Ciliwung watershed. It can be seen that the Hydrologic Soil Group that dominates the Upper Ciliwung watershed area is group A. Where this type A has the lowest run-off potential. So that water is absorbed well into the soil and allows high soil water content. Group A usually consists of sand, clay sand or sandy loam. This land has a relatively high water transfer value.
4. Conclusion
Based on the results of the research that has been done, then we get several conclusions from this study:

- The infiltration rate in the Upper Ciliwung watershed is based on field research, to determine the distribution of the Hydrologic Soil Group, varying between 0.15 – 12.6 cm / hour.
- After comparison, the distribution of the Hydrologic Soil Group obtained from the infiltration rate values has some differences with the distribution of the Hydrologic Soil Group according to the Geospatial Information Agency. According to the Geospatial Information Agency, the Hydrologic Soil Group in the Upper Ciliwung watershed consists of groups A, B, and D. While based on the infiltration rate research in the field, the Hydrologic Soil Group in the Upper Ciliwung watershed consists of groups A, B, and C.
- Based on the distribution map of the Hydrologic Soil Group classification in the Upper Ciliwung watershed, results show that the existing Hydrologic Soil Group is dominated by group A. This HSG A group has a high infiltration ability and low run-off potential.

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